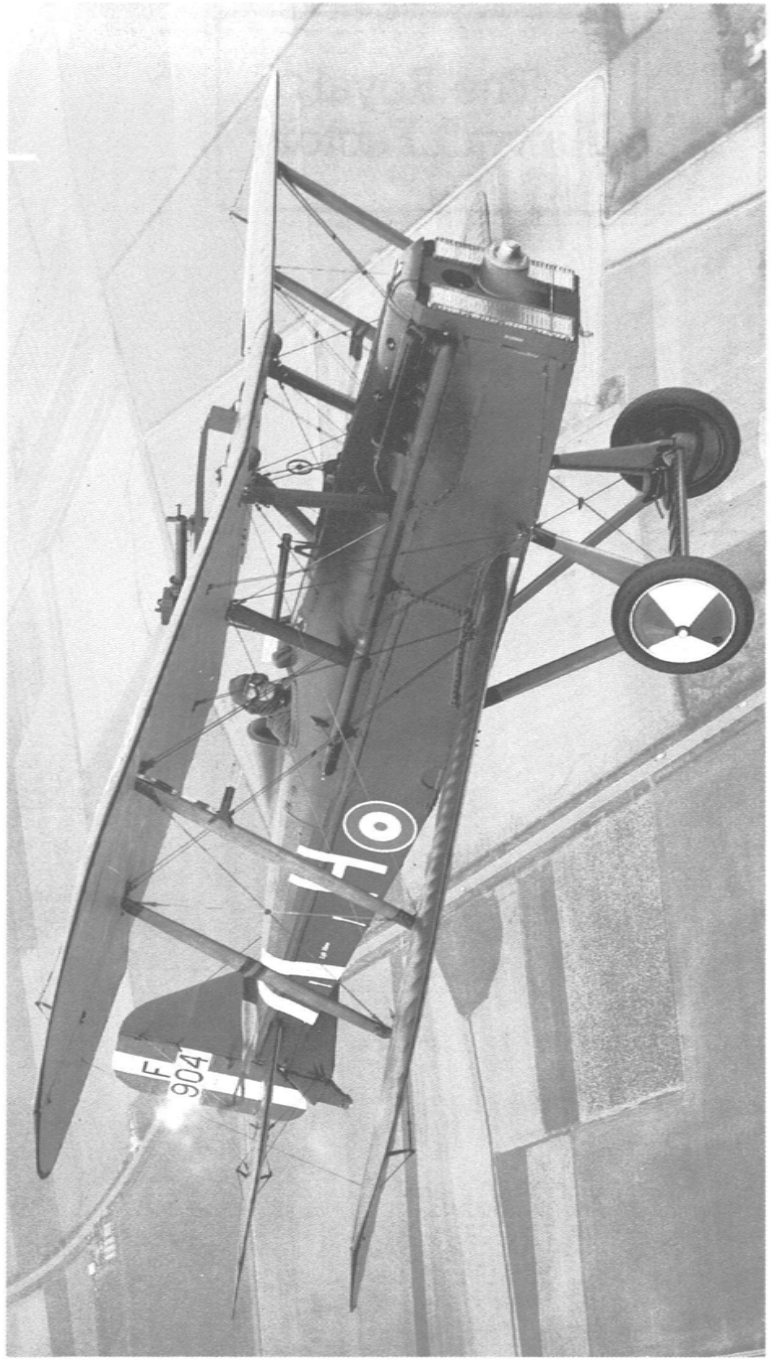

A fine air-to-air study of the Shuttleworth Collection's S.E.5a, G-EBIA/F904, taken on April 11, 1977, shortly after its first flight following the replacement of the geared 200hp Hispano-Suiza engine by a direct-drive 200hp Wolseley Viper. (*Air Portraits*)

The Royal Aircraft Factory

Paul R Hare

PUTNAM

This book is dedicated to
Leonard E Opdycke
without whose inspiration and encouragement
it would never have been written.

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CONTENTS

Acknowledgements iv
Introduction ix
Prehistory 1
A new era begins 24
Aeroplanes again 36
Military and other trials 52
Tested in battle 68
Enemies in high places 91
Change and decay 103

AIRSHIPS

Nulli Secundus 115
Baby/Beta 117
Gamma 120
Delta 123
Eta 125
Epsilon 126

AEROPLANES

A.E.1 127
A.E.2 127
A.E.3 127
Aerial Target 129
B.E.1 131
B.E.2 136
B.E.2a 140
B.E.2b 145
B.E.2c 146
B.E.2d 159
B.E.2e, f and g 160
B.E.3 164
B.E.4 167
B.E.5 169
B.E.6 170
B.E.7 171
B.E.8 171
B.E.8a 175
B.E.9 177
B.E.9a 180
B.E.10 180
B.E.11 181
B.E.12 182
B.E.12a 186
B.E.12b 188
B.S.1 190
B.S.2 192
C.E.1 193
F.E.1 196
F.E.2 199
F.E.2a 204
F.E.2b 207
F.E.2c 214
F.E.2d 215

F.E.2e, f, g and h 218
F.E.3 (A.E.1) 219
F.E.4 221
F.E.5 224
F.E.6 225
F.E.7 226
F.E.8 227
F.E.9 231
F.E.10 235
F.E.11 236
F.E.12 236
H.R.E.2 237
H.R.E.6 237
N.E.1 237
R.E.1 240
R.E.2 244
R.E.3 248
R.E.4 249
R.E.5 249
R.E.6 253
R.E.7 253
R.E.8 258
R.E.8a 267
R.E.9 267
S.E.1 269
S.E.2 272
S.E.3 276
S.E.4 276
S.E.4a 280
S.E.5 283
S.E.5a 288
S.E.5b 295
S.E.5E 297
S.E.6 297
S.E.7 297
T.E.1 298
Appendix 1 – Prototype production 299
2 – Production machines 300
3 – Royal Aircraft Factory engines 304
4 – Survivors and reproductions 307
Index 313

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Introduction

It is remarkable that a small English town with a population of less than 50,000, and possessing neither historical significance nor architectural merit, should become world famous. That its fame should endure is extraordinary. Farnborough, in Hampshire, is such a town, known to almost every inhabitant of the British Isles, and to many millions around the world, as the venue for the spectacular biennial air shows hosted by the Society of British Aerospace Companies. Yet, apart from enjoying these events, few people give more than a passing thought to the existence of the Royal Aerospace Establishment (RAE: the Royal Aircraft Establishment until May 1, 1988), the Government's research centre, whose 1,100-acre aerodrome, with its 7,500ft runway, is their venue. Fewer still understand its precise function, or realise that its history goes back well before mankind realised its dream of flight, and that the first successful British airship and aeroplane were both products of the antecedents of today's RAE. Indeed, what is generally recognised as the first powered, sustained, and controlled aeroplane flight in Great Britain was made on Farnborough Common, the site of the RAE's aerodrome, by a machine designed, built, and flown by those employed there.

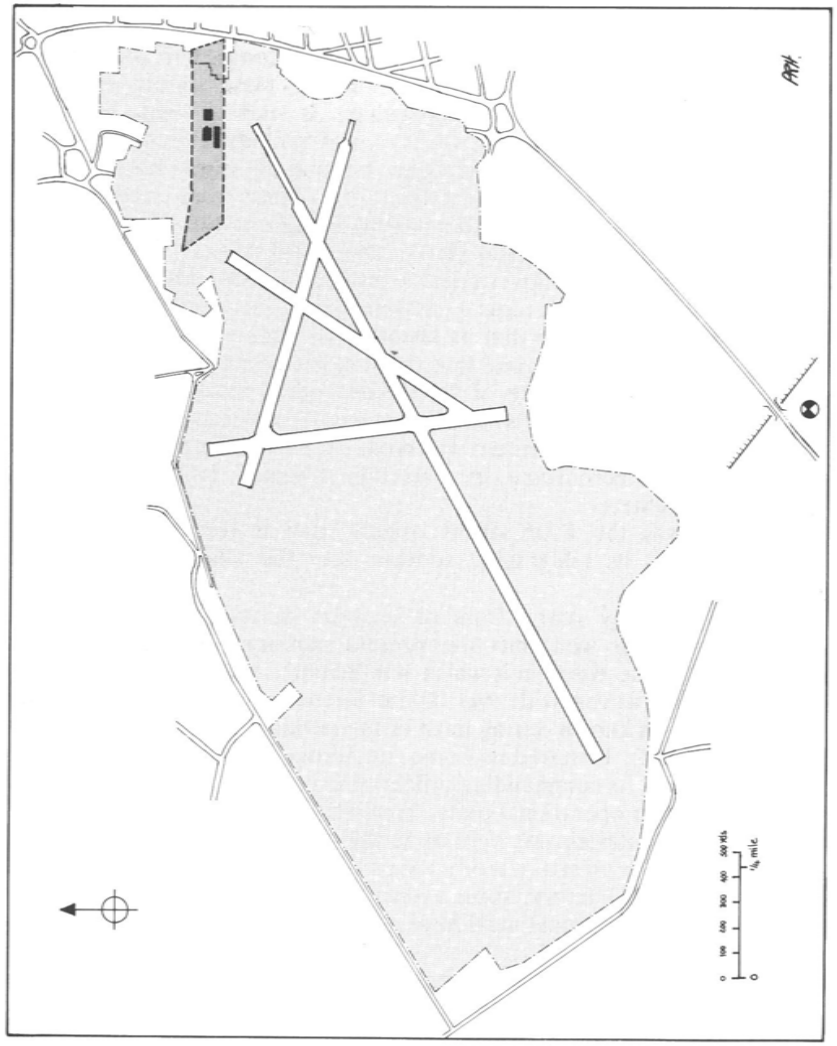
So proud was the RAE of its origins, that it retained 'Ballooning Farnborough' as its telegraphic address until the telegram service was discontinued.

For a great many years, from its creation during the height of the Victorian era until well into the present century, the operation and management of the Army unit which was Britain's embryo air service was inextricably interwoven with that of the forebears of the Royal Aircraft Factory (as it was known during most of the period with which this book is chiefly concerned). It shared its home, numerous personnel, and even, on several occasions, its commanding officer. The research establishment (now the RAE) and the operational units, from which grew the RAF, continued to share the same aerodrome right up to the outbreak of the Second World War. Therefore, to present a more complete picture of the development of the Royal Aircraft Factory, some events relating more specifically to the history of those operational units have also been described in the following narrative.

As military units the Royal Aircraft Factory's antecedents were far more occupied by the needs of the day than by those of the future, and many of the records of their work, where any were kept at all, leave much to be desired as far as the present-day historian is concerned. Many early flight reports lack such fundamental details as times, meteorological conditions, and even, on occasion, the pilot's name. Much of their early work was conducted using an empirical, rather than an analytical approach, with experiments being conducted on an apparently haphazard basis.

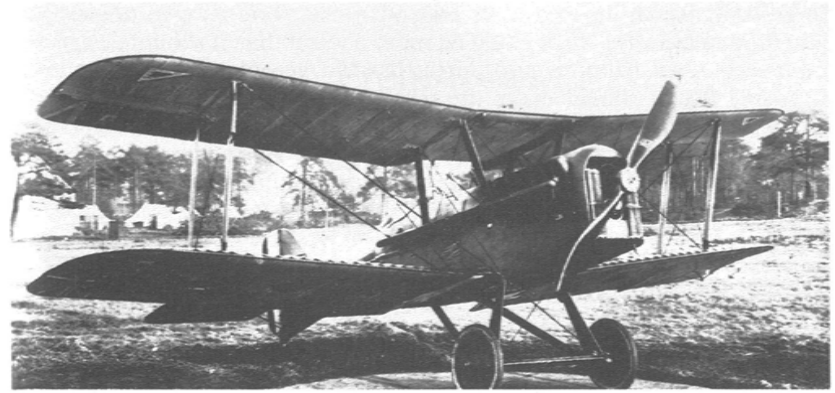
In addition, for reasons which will become clear, various subterfuges were employed to conceal the precise nature of some of the Factory's

activities from its Whitehall masters. Many of the 'cover stories' produced to achieve this end have since passed into aviation history, further complicating research into this period.



This plan of the modern RAE shows the position of the Royal Aircraft Factory site to the north east, and its previous Aldershot site, approximately two miles to the south.

Royal Aircraft Factory staff designed a great many of the aeroplanes used by the British Army and, later, the Royal Air Force before and during the First World War, and nurtured the careers of many men, such as Geoffrey de Havilland and Henry Folland, who went on to achieve well-deserved



Rival British fighters, the Sopwith Camel and the Factory's S.E.5a (top). Together they finally wrested aerial supremacy from the Germans.

fame as aeroplane designers in private industry. But the Factory was the target of a great deal of criticism, much of it unwarranted or misdirected, from the trade and certain sections of the press. One of its creations, the S.E.5a, vies with the Sopwith Camel for the title of the most successful Allied fighter of the Great War. Another, the B.E.2, which was undoubtedly one of the best aeroplanes of the prewar period, went on to be ridiculed and to become the subject of questions in the House of Commons. This led, in turn, to two judicial enquiries and, thereby, to the downfall of the Royal Aircraft Factory and, indirectly, to the creation of the Royal Air Force.

The products of the Royal Aircraft Factory were designed for experimental purposes—for research or to achieve specific aims, not for production or profit. At a time when aeroplane factories were non-existent, or counted their annual output in single figures, perhaps only a Government organisation could perform the academic investigation necessary to determine of what use the new science of aviation might be to the military forces.

To an army which developed its own weapons, shod its own horses, and built its own railways, what could be more natural than it should design and produce its own balloons and, later, its own aeroplanes? It is far more surprising that it should make the results of its research available to the public and to the trade. Yet that is what it did, issuing a constant stream of reports and technical papers on the strength of materials, aeroplane stability, and a host of other aeronautical topics which were then issued as *Reports and Memoranda* (*Rs & M*) by the Advisory Committee for Aeronautics (later renamed the Aeronautical Research Committee)

B.E.2as of 2 Squadron RFC fitted with flotation bags in case of a need to ditch during their flight across the Irish Sea.
(JM Bruce/GS Leslie)

Today its achievements are largely forgotten and its creations are often held in contempt. Evidence of its proud existence is ignored—save, perhaps, at the Farnborough site, where a handful of original buildings remain, where the memory of its Superintendents is perpetuated in road names, and where even the newest RAE recruit refers to the main site as 'The Factory', perhaps without knowing why.

Prehistory

The organisation which was eventually to become the Royal Aircraft Factory, and thus the present-day RAE, first took up residence on its current site at Farnborough as early as May 1905, but its history can be traced back many years before that date, to a time when powered flight still remained a dream.

The attention of the British War Office appears to have first been focussed on aeronautics in 1862. Capt F Beaumont and Lt George Glover, both of the Royal Engineers, who had observed the successful employment of tethered observation balloons by the Confederate forces during the American Civil War, advocated the formation of similar balloon units within the British Army. Early the following year experimental ascents were made at Woolwich and Aldershot, using a coal-gas balloon hired from Henry Coxwell, a famous showman and balloonist, and operated by him. While these experiments clearly demonstrated the value of the reconnaissance balloon, it was decided, in 1865, that the amount of work needed to develop a truly efficient system, tailored to the needs of the Army, was not justified in what were described as 'times of profound peace'.

Glover continued his efforts to convince his superiors in Whitehall of the military value of observation balloons, repeatedly drawing attention to their successful use by other nations and in various minor wars. Official interest was reawakened on several occasions, and some research was undertaken to determine the most efficient method of producing hydrogen, and to discover the material most impervious to it from which balloon envelopes could be made, but no conclusions were reached in either case.

In 1873 a proposal was made to provide two balloons, together with a transportable apparatus for generating hydrogen, for an expedition to Ashanti. This was abandoned when it was realised that the equipment could not be assembled in time to accompany the expedition.

Finally, in 1878, the War Office accepted that there was, after all, scope within the British Army for the employment of balloons. Capt James Lethbridge Brooke Templer, already accomplished in the fashionable sport of free-ballooning, was directed to design and build a balloon for service use. He was to be assisted in his endeavours by Capt H P Lee, who was then stationed at Woolwich Arsenal, where the balloon was to be made. Labour was provided by men of the Royal Engineers, and an allocation of £150 was made to cover the cost of materials, a sum which has frequently been referred to as the first ever 'Air Estimate'.

Capt Templer was not a regular soldier, but was a member of the 2nd Middlesex Militia (later incorporated into the Kings Royal Rifles). This seemingly insignificant fact was to prove of great benefit to early British military aviation, because he could, if appropriate, be treated almost as though he were a civilian employee and thus not be posted, or assigned to other duties, in the supposed interests of furthering his career, or of military efficiency. As a consequence he was able to devote the whole of his

considerable energy and talent (and occasionally some of his private income) to the needs of the infant air service.

Templer's creation, appropriately named *Pioneer*, was designed for hydrogen, which not only had the greatest lifting power, but was reasonably easy to manufacture. *Pioneer* therefore needed a capacity of only 10,000 cu ft, was fairly portable, and presented a far smaller target to hostile fire than a coal-gas balloon of equal lift. Its envelope was of varnished cambric and, complete with basket and ancillaries, cost £71. Its first ascent was made, with complete success, on 23 August, after which Templer used it, together with his own coal-gas balloon *Crusader*, to instruct Royal Engineers personnel in the art of ballooning. This small unit rapidly became known, at first unofficially, as the 'School of Ballooning'. In addition to his normal salary Templer was given an allowance of ten shillings per day for carrying out this instruction, although it is not clear whether this was intended to be recompense for the hire of *Crusader* or the first example of 'flying pay'.

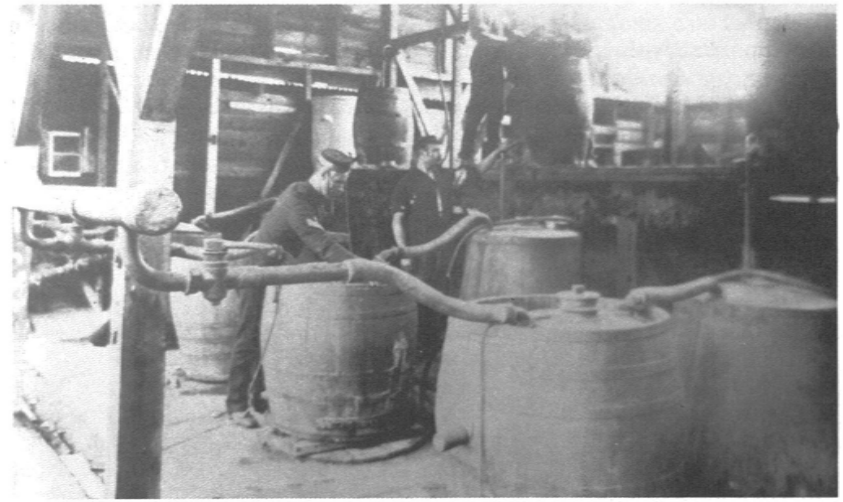
During the following year a Balloon Equipment Store was formally established at the Royal Engineers' Woolwich Depot under the command of Capt Lee. He clearly had an eye to the future, for not only had he assisted Capt Templer in the building of *Pioneer*, but he had also begun experimenting with the design of an apparatus for producing hydrogen in the field, by the action of acid upon zinc.

By the end of 1879 Templer's unit had five balloons in service, and it took part, with acknowledged success, in the Aldershot manouvres of 1880 and 1882, with Capt Lee in command on the latter occasion.

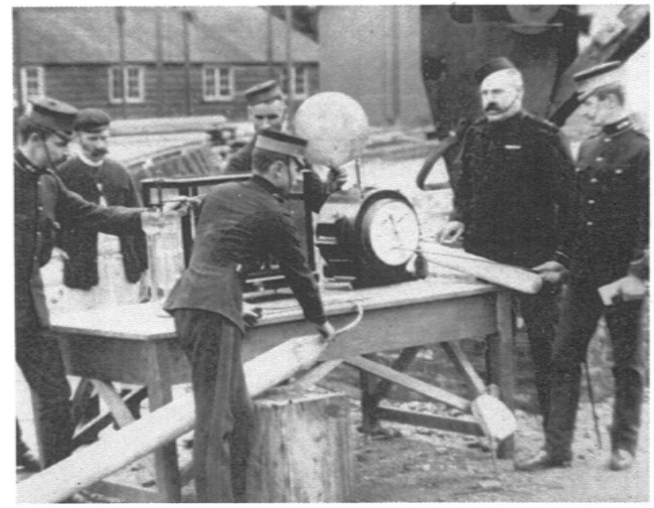
Late in 1882 the Balloon School and the Balloon Equipment Store were moved to the School of Military Engineering, St Mary's Barracks, Chatham, Kent, where they took over some vacant buildings as storerooms and roofed over a disused ball court to provide a balloon erecting shop. Here Templer was able to conclude his search for the ideal balloon fabric. He first experimented with silk treated with linseed oil, which proved a great improvement over previous materials, a small balloon, *Sapper*, being constructed therefrom. Finally, in 1883, the Balloon School personnel built the balloon *Heron*, which had an envelope manufactured from goldbeater's skin, a material derived from the intestines of cattle or oxen and normally used in the preparation of gold leaf—hence its name. The method of joining together the relatively small skins, which were brought from local abattoirs, was at that time known only to the Weinling family (Orthodox Jews originally from Alsace), members of which were therefore taken into War Office employment to carry out the work. *Heron* proved so successful, its envelope not only being stronger and lighter than all others of similar capacity, but also being almost totally impervious to hydrogen, that goldbeater's skin was then used for all subsequent British Army balloons and for early airships. Members of the Balloon School staff eventually assisted the Weinlings in working with it.

By 1884 the Balloon School had standardised on two sizes of balloon for normal use, the 'T' class of 10,000 cu ft, and the 7,000 cu ft 'S' class, which was considered adequate to lift one fairly light observer under favourable

climatic conditions, but had very little reserve of ballast with which to adjust buoyancy or to control the balloon if it broke away. Since a small balloon obviously needed less gas, and presented a more difficult target to an enemy, an 'F' class of 5,600 cu ft was developed for use in low-lying countries, but it was not used in service.



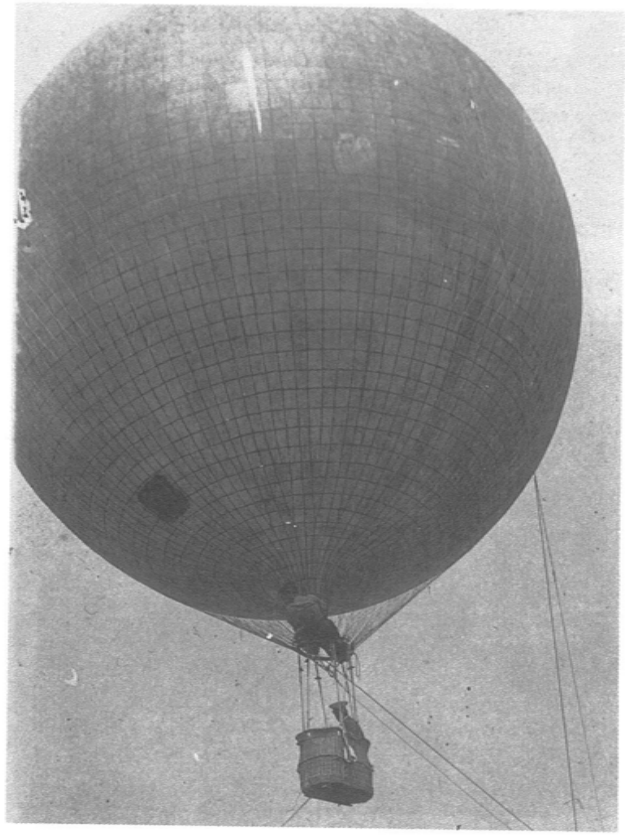
The manufacture of hydrogen by the zinc-acid method at Aldershot in 1896.



A carefully posed photograph of men of the Balloon School filling hydrogen cylinders at the Aldershot site. Col Templer is second from the right.

Until this time the hydrogen with which the balloons were inflated had been manufactured as and when required, a lengthy and rather dangerous procedure using the zinc-acid process. However, in 1884 a means was developed whereby the gas could be compressed at pressures of up to 1,800lb/sq in and stored in steel cylinders (or 'tubes' as they were known at the time), special wagons being designed for their safe transportation in the field. Because the gas produced by the zinc-acid method was frequently contaminated with the acid, and was thus much too corrosive for use, experiments for the production of hydrogen by the electrolysis of water were continued, although without immediate success.

As part of its effort to perfect all the ancillary equipment necessary for efficient military ballooning, Templer's team also directed its considerable energy into the development of winches and traction engines (affectionately known as 'steam sappers') to move the balloon and tube wagons in service. However, much use was also made of the traction engines on behalf of other



Two men of the Royal Engineers aloft in a tethered balloon.
(via CH Clover)

Royal Engineers units. This practice, together with Templer's generous but unauthorised gesture in allowing the Balloon School's engineering facilities to be used by other units within the Aldershot command, created problems later on, and led to the first of several occasions on which the Balloon School, or its successors, were instructed to adhere more closely to their designated sphere of involvment.

A Balloon School detachment participated in the summer manoeuvres of 1890 with such conspicuous success that, the following year, a Royal Engineers' Balloon Section was formed to operate balloons in the field, leaving the School to concentrate on instruction and development. The Balloon Equipment Store was incorporated into the new unit, which was based at Aldershot, on a site near to the Basingstoke Canal, adjoining the RE (Stanhope) Lines, and it was placed under the command of Lt H B Jones. The unit's initial complement was three officers and thirty-three other ranks. As this was Britain's first operational aircraft unit, it can justifiably be said to mark the conception, if not the birth, of what would eventually become the Royal Flying Corps, and later the Royal Air Force.

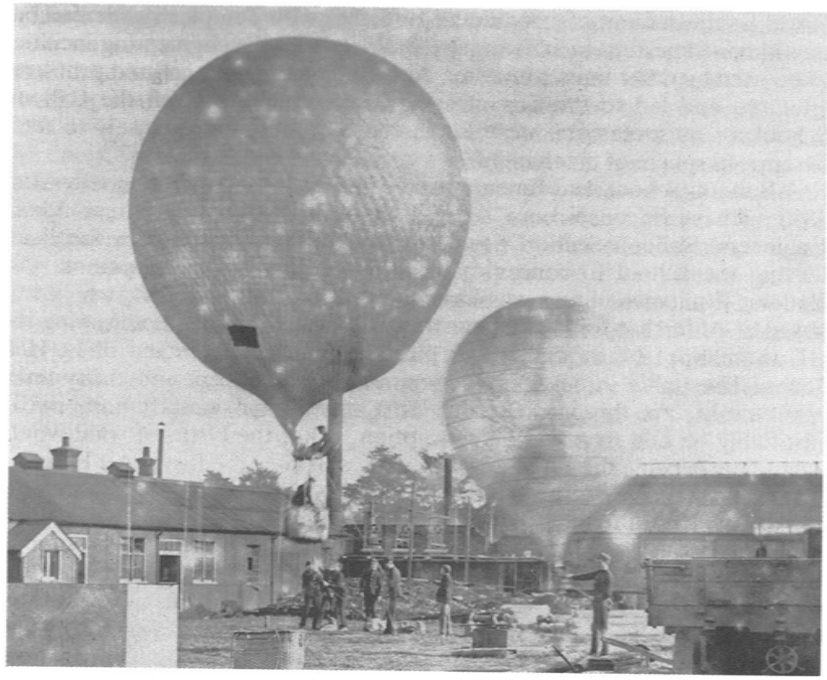
Arrangements were also put in hand to relocate the School of Ballooning to Aldershot, still under the command of Templer, who had, by this time, been promoted to major and who was now officially titled Instructor in Ballooning. This move was intended to bring the balloonists closer to the mainstream of British Army life, for while they were themselves a unit of the Royal Engineers, whose base was at Chatham, it was the infantry and artillery which actually benefited from the improved reconnaissance provided by the balloons.

The new site was to the South of the Basingstoke Canal, near Aldershot Wharf. A number of huts were erected there, as were two steel-frame buildings clad in corrugated iron, one large enough to hold several fully inflated balloons and the other to serve as a workshop and store, the construction of which delayed completion of the move until 1892. A steam engine provided power to an overhead shaft running through the long narrow building, and belts from this shaft drove all the machine tools, as was normal practice at the time. The workshops were unheated.

Once the move to Aldershot had been completed, investigations into the production of hydrogen by the electrolysis of water were finally concluded. After consultation with the staff of several factories where the process was undertaken commercially, a satisfactory system was eventually designed and a manufacturing plant constructed. This came into service in 1896, and could produce 10,000 cu ft of pure hydrogen in twenty-four hours. The cost of its production was offset by the sale, to industry, of the oxygen which was a by-product of the process.

In June 1894 a man-lifting-kite section was added to the Balloon School, using equipment designed by Capt B F S Baden-Powell, whose brother was later to achieve fame as the founder of the Boy Scout movement. However, stability problems in gusty conditions brought these experiments to an early end.

The name 'Balloon Factory', which had been in common use for a number of years rather than the proper title of School of Ballooning, was



Royal Engineers personnel preparing spherical balloons at Aldershot in 1898. The restricted nature of the site is all too apparent.

officially recognised on 1 April 1897, when the unit was taken out of the control of Aldershot Command. Instead, Templer, who had by now attained the rank of lieutenant colonel, was designated its superintendent (his previous title of Instructor in Ballooning had become somewhat inappropriate to the wide range of activities actually undertaken) and made directly responsible to the Inspector General of Fortification at the War Office. His salary was increased to £700 per annum (equivalent to about £30,000 at 1989/90 values).

The outbreak of the Boer War in 1899 saw the Balloon Sections on active service for the first time, and demanded greatly increased production by the Factory, together with the development of a great deal of new equipment now found necessary to meet the needs of operating under war conditions. All this work had to be carried out without the inspiration and guidance of Col Templer who, on the 2 December, set sail for South Africa, not to serve with the balloon units but, because of his acknowledged skill with steam traction engines, to act as Director of Road Transport. Although he performed these duties with all of his usual enthusiasm, it is difficult to comprehend what strange sense of adventure could have prompted him to accept the post.

Meanwhile, under the direction of Col J P L Macdonald, its acting Superintendent, the Factory developed two new classes of balloon. These were the 'A' or 'Albion' class of 13,000 cu ft, and the 'B' class of 11,500 cu ft. They were necessary because the standard 10,000 cu ft 'T' class had been found to be deficient in lift in the hot and rarefied air of the South African plateaux.

Col Templer returned to his former post as Balloon Factory Superintendent early in 1901, Macdonald having left to take command of a balloon detachment dispatched to China to assist in quelling the Boxer rebellion. While Templer's enthusiasm for balloons seems to have been undiminished, his interests had widened to include dirigible balloons. Early the following year he travelled to the French Government's Aeronautic Research Establishment at Chalais Meudon, Paris, where a wide range of experiments had been conducted, and visited Alberto Santos-Dumont who, the previous year, had circled the Eiffel Tower in his diminutive Number 6 non-rigid airship, powered by a tiny petrol engine of only 3hp.

Templer was obviously impressed by all that he had seen, and upon his return he sought, and was granted, War Office permission to conduct airship experiments of his own. Unfortunately, in that year's budget the Balloon Factory's allocation of funds was cut from £12,000 to £6,000. Nevertheless, work was started on the fabrication of an airship envelope with a capacity of 50,000 cu ft, which was to be made of five superimposed thicknesses of goldbeater's skin. The financial restraint under which the Factory was obliged to operate meant that this envelope was not to be completed until 1904, when it was found to be too heavy to allow adequate buoyancy to lift the anticipated weight of the car and the engines necessary to propel it. Work therefore started on a second envelope of similar capacity, but using only three layers of skin. The first envelope served as a pattern, the second being built over it. The original was then deflated and removed through an aperture in the new envelope.

During the latter part of 1903 the future of British military ballooning (as the whole field of aeronautics was then described) was considered by a Committee of Enquiry formed to ascertain what improvements might be made, consideration being given to recent experiences in war, and to progress made in other countries. The committee comprised three distinguished soldiers (including Lt Col H H Wilson who, as Field Marshal Sir Henry Wilson, became Chief of the Imperial General Staff during the Great War), a civilian financial advisor from the War Office and, as secretary, Lt Col John E Capper RE, who had recently taken over command of the Balloon Sections.

Among its recommendations, which were published in January 1904, was a suggestion that the Balloon Factory should be instructed to adhere more closely to its designated sphere of operations, and that all work on traction engines and other such equipment of, at best, peripheral connection with balloons, should cease. The committee further recommended that attention would need to be focussed upon the development of dirigible balloons (airships), man-lifting kites, balloon winches, signal balloons, and photographic equipment. A proposal was also made that the Commandant of the

Balloon Sections (Lt Col Capper) should be, *ex officio*, assistant superintendent of the Balloon Factory. The final proposal was that the Factory should be relocated, as its present site, known as 'Balloon Square', which covered an area of only some 2½ acres, was far too enclosed and offered no potential for further development.

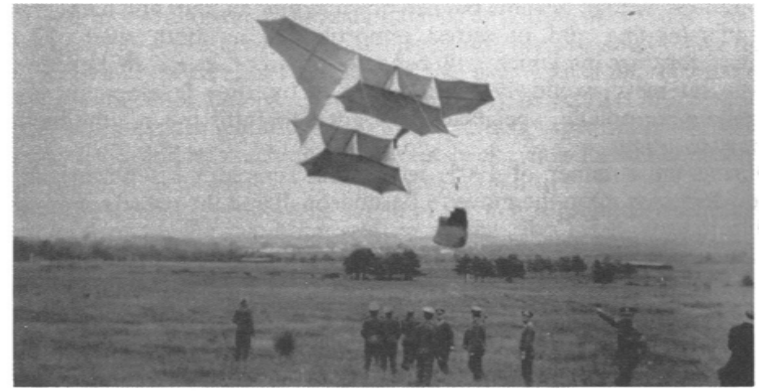
After lengthy deliberations and a long search which explored much of central and southern England, a new site, just a few miles away at South Farnborough, was finally selected. This site, which had a total area of some twenty-two acres, was to the west of the Aldershot to Farnborough road, just behind the Swan Inn and at the edge of the open spaces of Farnborough Common. To reduce costs as much as possible, men of the Royal Engineers were used to clear trees, level the ground, and erect a fence around the site. During the winter of 1904/05 the existing Balloon Shed, gas holders and hydrogen generating plant were dismantled and removed to the new site, their actual transportation being undertaken with the aid of the traction engines which had found so little favour with Col Templer's superiors. Such damage was done to the main road by this move that a bill of £675 towards the cost of the necessary repairs was later raised against the Army by Hampshire County Council. The re-erection of these buildings does not appear to have been completed until August or September 1906, leaving the Factory virtually homeless in the interim.

At the same time as the existing buildings were being moved by Army personnel, a private contractor was engaged to construct a new airship shed alongside the relocated balloon shed, to which the workshop and stores, which had previously been a separate building, was now attached. The new shed was an impressive 160 feet long, 82 feet wide, and 72 feet high. Its doors, which were the largest in the country at that time, would enable the British Army's first airship to be completed and erected inside, using the goldbeater's-skin envelope which had been started some three years earlier. Equally impressive was the cost, for the vast building, excluding its foundations, had been erected for a sum barely in excess of £3,000. Unfortunately, to fit within the site with true military precision, the new

S F Cody, assisted by his sons (also wearing sombreros), launches a string of man-lifting kites some time before their adoption by the Army.
(Museum of Army Flying)

hangar was erected with its axis aligned exactly east-west, forty-five degrees out of line with the prevailing south-westerly winds. In consequence, airship operations were sometimes restricted on days when they would have been perfectly possible had the hangar faced more exactly into the wind.

The Balloon Factory's work continued as best it could during the upheaval of moving and, in June 1904, extensive tests were conducted to evaluate the effectiveness of a new system of man-lifting kites which had been developed by an expatriate American showman named Samuel Franklin Cody. This system used a number of biplane box kites, flown on a common cable with a smaller pilot kite to steady the line, and a huge carrier kite, equipped with a balloon basket or bosun's chair, which could ascend the cable under the control of its occupant.



S F Cody (in sombrero) and men of the Royal Engineers launch a man-lifting kite.
(SFJ and P Cody)

Cody's kite system proved far superior to anything previously tried, and observers were lifted to altitudes greater than 1,000ft on several occasions during the trials, without the dangerous instability in gusty conditions which had marred previous systems. Because the kites became effective at similar wind velocities to those at which balloons became unstable, the system was recommended for adoption by the British Army. Cody, who was a Texan by birth, and who had variously been a cowboy, a prospector, a horse-dealer, a showman, an actor and a playwright, was engaged to instruct Balloon School personnel in their operation. He was initially engaged for three months only, but his contract was repeatedly renewed until, finally, in April 1906, he was appointed 'Chief Kite Instructor' at a salary and status approximately equivalent to that of a British Army colonel.

In the autumn of 1904 Col Capper, accompanied by his wife, Edith, visited the St Louis World's Fair, which was held to celebrate the centenary of the 'Louisiana Purchase' which had brought the region within the United States of America. He went as the representative of the War Office,

intending to study the many aeronautical exhibits on display, but found these to be something of a disappointment, as did the organisers. His long journey was far from wasted, however, as he made calls upon a number of individuals who had made significant contributions to aviation. These included Octave Chanute, the author of *Progress in Flying Machines*; Professor Samuel Pierpont Langley of the Smithsonian Institution; and the Wright brothers, who had already made the first powered aeroplane flights. As a result of the last of these visits, which was made entirely upon his own initiative, Capper included in his report to the War Office a recommendation that Britain should seek to purchase an aeroplane from the Wrights. This recommendation was accepted, and negotiations were duly opened by a sporadic exchange of correspondence, but initially the Wrights did not regard their aeroplane as being sufficiently developed to be sold. Later negotiations were to become bogged down in bureaucracy and hampered by misunderstanding and un-seized opportunities on both sides. Finally, Capper, for reasons which will become apparent, came to believe that British interests would be better served by the development of an indigenous aeroplane, specifically designed to fulfil the requirements of military scouting.

During the summer of 1905, while Col Templer's attention was still largely focussed upon the move to Farnborough and the construction of the airship hangar, S F Cody, whose restless mind was always seeking a new challenge and who was already working towards manned flight, designed a biplane 'glider-kite' which had a wingspan of over fifty feet and an empty weight of only 116lb. This was built at the new Farnborough factory and was tested, with the assistance of personnel from the Balloon Sections, by flying it up to the desired altitude—usually around 100ft—in the normal kite manner, and then releasing it to return to earth as a glider, its pilot occupying a prone position on the lower wing. This craft, which had numerous triangular fin surfaces above the upper wing and below the lower wing, was equipped with small winglet ailerons for lateral control, one of the earliest recorded uses of this form of control. The inclusion of these ailerons, together with the adoption of the prone pilot position introduced by the Wrights, demonstrated Cody's awareness of general aeronautical development and his willingness to learn from others.

Numerous glides were made across the clear expanse of Farnborough Common, including several in which the craft travelled in excess of 700ft. The trials ended when a sudden gust of wind caused a sideslip and the pilot, Cody's younger son, Vivian, was badly injured in the resulting crash, although he eventually made a complete recovery and continued to work at Farnborough until his retirement in the 1950s. The glider was not repaired, most probably because it was felt that the experiment had by then served its purpose. Cody was already planning another experiment.

Having reached the age of 60, Col Templer retired in May 1906, but was paid an allowance of £300 per annum, in addition to his pension, to retain his services as a part-time consultant for a further two years, principally so that he could supervise the completion of the airship.

He was replaced as Superintendent of the Balloon Factory by Col

Capper, who also retained his previous position as Commandant of the Balloon Sections, thereby leaving the Factory without an Assistant Superintendent for the time being.

In June Capper managed to obtain War Office authority to spend £600 upon gliding experiments, perhaps indicating that both he and his superiors had already discounted the possibility of purchasing a Wright machine, and had accepted that they would need to develop their own aeroplane (even though negotiations with the Wrights would continue for several more years). Significantly, June 1906 also saw the arrival at the Factory, at Capper's invitation, of Lt John William Dunne, who had presented a convincing case for the construction of an inherently stable aeroplane of his own design. At that time Dunne was receiving only half pay, as he was excused from normal duties owing to ill health. He was not at first officially employed at Farnborough, although the War Office was fairly quick in acknowledging a *fait accompli* and recognised his presence on Capper's staff. He was, however, to continue on half pay, with some increments in October 1907, until finally restored to full pay in April 1908. Following several years experimentation with small folded-paper models, Dunne's idea was for a tailless machine with swept-back wings having considerable 'washout' (reduced, or negative, incidence) at their tips.

This was, almost certainly, the origin of the near-obsession with inherent stability which was to colour the Factory's thinking throughout its existence, and which was to lead eventually to the B.E.2c, to questions in the House of Commons, and to the demise of the Factory in that form.

Once at Farnborough, with the Factory's fairly extensive facilities to assist him, Dunne began to experiment with somewhat larger models than hitherto, including one with a wingspan of approximately three feet. This was constructed of fabric and umbrella ribs, and Dunne saw it as his next step towards the eventual design and construction of a full-sized machine.

During September and October of this year Alberto Santos-Dumont made the first officially observed powered aeroplane flights in Europe. By this achievement he established not only that such flight was possible, a fact of which many people remained unconvinced, but that it was possible without the assistance of the Wright brothers. This further reduced the likelihood of the negotiations between the Wrights and the War Office reaching a successful outcome, and encouraged all those pioneers, including Cody and Dunne, who were still striving to fly with their own aeroplanes.

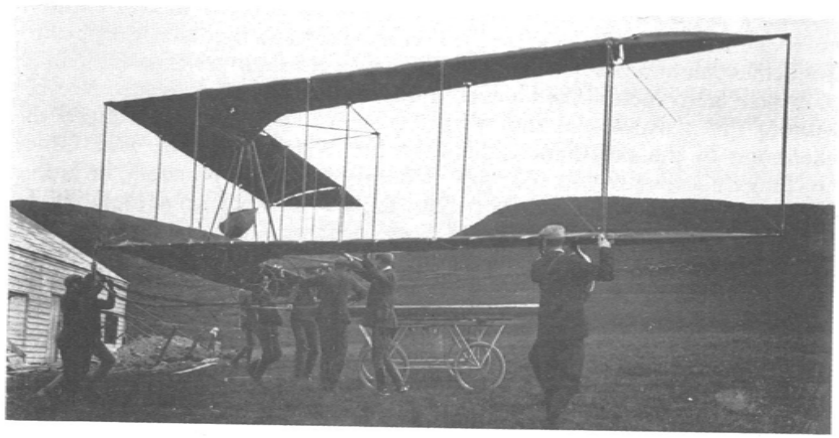
In December 1906 the Balloon Factory's first windtunnel was completed, its design being based upon that of a tunnel at the National Physical Laboratory (NPL) at Teddington, with whom the Factory had a close and co-operative working relationship. The Farnborough tunnel was built in one corner of the airship hangar, and had a cross-section of approximately twenty-five square feet. It was more than fifty feet long, with a forty-eight-inch-diameter electrically driven fan providing the airflow. Its operator was Capt A D Carden, who became the Factory's Assistant Superintendent early in 1907 and who, despite having only one arm, was responsible for much of the Factory's technical work at this time. The windtunnel appears to have been used initially for propeller testing and to

determine the best streamline shape for struts and airship envelopes. However, after a short time it fell into disuse and the Factory reverted to using the facilities at the NPL. Although the reason for this action is not recorded, the availability at the NPL of staff trained in windtunnel operation may have been a contributory factor.

It was also in December 1906 that authority was granted for the purchase of a 50hp Antoinette V-8 engine from its French manufacturers, at a cost of approximately £450, to provide the motive power for the Factory's airship. This engine was selected simply because it was easily the best engine available, particularly with regard to power-to-weight ratio, and Cody was sent to Paris to collect it and to receive instruction in its operation and maintenance. This was, perhaps, an indication that his involvement with the work being carried out at Farnborough had already progressed far beyond that which his title of 'Kiting Instructor' might have suggested, and that he and Capper, despite their obvious dissimilarities, had established a good working relationship, and possibly even friendship.

Early in the new year Cody carried out experiments with the machine that was clearly his next step on the road to the building of an aeroplane. This, the Power Kite, was of broadly similar layout to one of his man-lifters, but had extensions fitted to the upper surfaces, twin triangular fins mounted on bamboo tailbooms, and a wheeled undercarriage. Power was provided by a 12hp three-cylinder Buchet engine which drove a pusher propeller via a chain. The pitch of the propeller blades was adjustable on the ground, to enable the maximum possible thrust to be obtained.

This craft was not intended to carry a pilot, being flown along a wire believed to have been suspended between a point within the airship hangar, where the machine was launched, to a mast some distance in front of it, to the west. Various sources claim that it was later allowed to fly free on



The inherently stable Dunne D.1 glider being lifted on to its launching trolley at Blair Atholl in the Scottish highlands.
(JM Bruce/GS Leslie)

Farnborough Common, but this seems to be a highly improbable suggestion, and no evidence has been found to support it. Nevertheless, the machine is considered to have been a success, demonstrating that powered flight was within the Factory's grasp.

Another project carried out early in 1907, in parallel with Cody's work, was the construction of a full-sized aeroplane in accordance with the ideas developed by Lt Dunne as a result of his extensive experiments. This craft, designated simply D1, was initially to be tested as a glider before fitting the propulsion system which had been designed for it by Capt Carden.

By arrangement with the Marquis of Tullibardine, eldest son of the Duke of Atholl, the flight tests took place, in secret, at a remote location near Blair Atholl, on his family estate in the Grampian highlands, during the summer of 1907. This desire for secrecy, especially when compared with the Factory's normal habit of operating from a public common, clearly illustrates the significance attached to Dunne's 'discovery'. Since Cody's work was an extension of his already well-known kite experiments, any attempt at secrecy would have been futile, and none was made. It was also entirely possible that Capper hoped to focus all attention on Cody, thereby allowing Dunne to work without distraction.

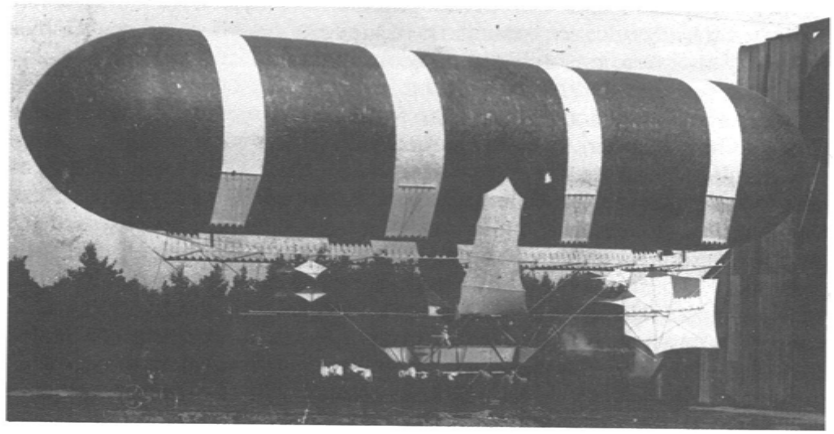
A number of successful glides were made, the craft being piloted by various officers from the Balloon School, as Dunne's frail health was not considered up to the task. A minor crash occurred while Capper was at the controls, during a brief visit to judge what progress was being made. The glider made contact with a wall, and flight trials were stopped pending repairs. During the course of this work the glider was converted into a powered aeroplane, the D1-B (the glider thus becoming, retrospectively, the D1-A). The propulsion system comprised twin propellers mounted on outriggers and driven, via belts or chains, by two 12hp Buchet engines, one of which had previously powered Cody's power kite. The two engines were coupled to a single shaft, and some initial difficulties were resolved when it was discovered that they had been installed so as to run in opposite directions.

It was intended that the powered aeroplane would be launched from a wheeled trolley running along a raised pathway of planks, laid to provide a reasonably level surface. Unfortunately the trolley ran off the planks during the first take-off attempt, and the machine was damaged to an extent which almost certainly would have required its return to Farnborough. It was felt that this would make it impossible to resume flight trials before the onset of winter, so the experiments were abandoned until the following year. The team's enthusiasm does not appear to have been diminished by this setback, and Capper seems to have had little trouble in convincing the War Office that they should be allowed to continue with the project.

Meanwhile the dirigible balloon (airship) envelope, originally started by Col Templer back in 1902, had not been forgotten. During the summer of 1902 the craft, which would be known as *Nulli Secundus* (a name it shared with one of King Edward VII's favourite racehorses) was finally completed, incorporating Templer's original ideas regarding its design. A tubular-framework keel suspended from four silk bands slung over the envelope

supported the long, narrow car which would house the engine and the crew.

Because Capt Carden was fully engaged in assisting Dunne with his aeroplane, the design of both the propulsion system and the control surfaces appears to have become the responsibility of S F Cody, due no doubt to his previous success with his power kite. Cody would probably have preferred to work towards achieving heavier-than-air flight, but he nevertheless produced a satisfactory arrangement of twin propellers, mounted on outriggers and driven via belts by the 50hp Antoinette engine, which was mounted within the car where it could be given constant attention. As in Cody's previous design, the pitch of the two-blade propellers was adjustable, and it is said that Cody determined the most effective angle by spinning them in a lathe to see how far the thrust from their slipstream would deflect a heavy nut suspended on a thread.



Nulli Secundus leaves its shed for its first flight on 10 September 1907. Note the additional width of the silk band which supported the weight of the engine.
(British Balloon Museum and Library)

On 10 September *Nulli Secundus* finally emerged from Farnborough's airship shed and was carefully ballasted to obtain the necessary balance between weight and lift. Then, with a crew of three on board (Col Capper, S F Cody and Capt W A de C King, then Chief Instructor in Ballooning), she made a short flight before engine trouble necessitated a return to her shed, this manoeuvre being accomplished with comparative ease. The expected instability in the rolling axis had not, in fact, occurred (nor would it, owing to the pendulum effect created by concentrating the majority of its mass—crew, engine and fuel—well below the envelope), and the large wings which had been fitted amidships to counteract such instability were therefore removed. Fore-and-aft stability, however, was far from satisfactory, and a large horizontal surface was added at the tail in an attempt to remedy this. Nonetheless, the flight was thought to have proved *Nulli Secundus* a success, and, in keeping with the spirit of the times, a medal was struck to commemorate the event.

The modifications were completed by 30 September, when the next flight trials took place. Further flights were made on 3 October, when she stayed aloft for over an hour, covering a total distance of eighteen miles. Two days later, with Capper and Cody aboard, she took off just after 10.30am and set course towards London at a height of about 1,000ft. The journey was uneventful, and *Nulli Secundus* reached the capital at around noon and passed over Buckingham Palace, where the German Kaiser was staying as a guest of his uncle, King Edward VII. His presence in London may well have influenced Capper's decision to make such a flight at that time, thereby demonstrating Britain's aerial prowess to a rival power. If the occupants of the palace were aware of the airship's presence, however, they gave no sign of it. *Nulli Secundus* then proceeded along Whitehall, where Capper proudly displayed it to his superiors, dipping it in triumphant salute over the War Office building. He then flew down the Strand, almost bringing London to a standstill as people everywhere stood and waved at what was, for all but a very few, the first airship they had ever seen.

Turning around the dome of St Paul's Cathedral, Capper began to realise that the south-westerly breeze which had thus far helped them along had freshened considerably, and that they would be unable to make sufficient headway against it to return to Farnborough. He therefore set course for Clapham Common, just south of the river Thames, hoping to land there. Such a large crowd had developed on the common, however, that the ground crew (who, lacking any official vehicle with a sufficient reserve of speed to keep pace with the airship, had followed in Cody's own motor car) were unable to reach them. Eventually a landing was made at a cycle stadium in the grounds of the Crystal Palace, further to the south, the ground crew having been informed of the destination by messages dropped in weighted bags.

Nulli Secundus had covered a distance well in excess of fifty miles in a flight time of 3hrs 20mins, and had set a new record for a non-rigid airship. This achievement was, with some justification, heralded as a triumph by the popular press, the airship's inability to fly against the wind being either not understood or simply ignored.

For five days the airship remained at the Crystal Palace, waiting for the wind and rain to abate sufficiently to make the return journey feasible, but there was no respite. Then, early on 10 October, she was caught by a sudden gust, tore loose some of her restraining pickets, and began to buck so violently that it appeared she might break free. To avoid the total loss of the British Army's only airship, the corporal in charge of the handling party quickly tied a sharp knife to a long pole and slit the envelope to deflate it. Deflated, too, were the Farnborough team who thus had to transport the airship's remains home by road.

The new year, 1908, which was to bring both triumph and tragedy for the Balloon Factory, saw Henri Farman fly a circular kilometre on 13 January at Issy-les-Moulineaux on the outskirts of Paris, to win the prize of 50,000 Francs offered by Ernest Archdeacon. (The Wright brothers had performed this feat many times in 1905, but their achievements were not widely recognised in Europe until Wilbur made flights there later in 1908).

At Farnborough, steady progress continued to be made in general aeronautical research, in the construction of balloons, kites and associated equipment, and in the rebuilding of *Nulli Secundus*, as well as in the design of aeroplanes in accordance with the differing concepts of Cody and Dunne.

On 1 April, in recognition of its status and achievements, the Factory was honoured by being renamed His Majesty's Balloon Factory.

The first of the HM Balloon Factory creations to take to the air was the airship, her slit envelope repaired. She had been rebuilt as a semi-rigid, with an enclosed understructure which helped to increase her maximum still-air speed to 22mph. In this form she was given the rather ridiculous and grammatically offensive title *Nulli Secundus II*. Several sources assert that her volume had been enlarged by increasing her diameter to twenty-six feet. This seems highly unlikely, and it is suspected that any increase was actually due to the measurement being taken while she was inflated to a greater differential pressure than previously, and that her expandable envelope was stretched more than usual. It was this feature which enabled her to maintain shape as hydrogen was released to reduce her buoyancy when the crew wished to descend. In airships with envelopes of fixed capacity this difficulty was overcome by the provision of a ballonet, a small chamber within the envelope which was inflated with air to take up the space vacated by the release of hydrogen.

Short test flights on 24 July and 14 and 15 August were sufficient to prove that the rebuilt airship was now seriously unstable, much of her pendulum stability having been lost by the conversion to semi-rigid form. In addition, overheating and continual full-throttle running had impaired the efficiency of the Antoinette engine to the point at which it became prudent to discontinue trials of the airship pending an engine overhaul. That, at least, was what Capper told his superiors, and it was almost certainly true, but in fact *Nulli Secundus II* was quietly acknowledged to be a failure, and was eventually broken up without any further attempts to fly her. *Flight* magazine was apparently quite philosophical about her failure. In a review of world aviation, published on 20 March 1909, her photograph carried the caption: '*Nulli Secundus* has had a brief and far from happy record, which, however, is in no way due to the Military Authorities, who do the best they can with the funds at their disposal'.

By early September Lt Dunne had returned to Blair Atholl. He was accompanied by a team of helpers which included Lt Westlake, who had been a member of the previous year's party, and a young militia lieutenant, Lancelot Gibbs, who was to act as pilot. They took with them a new glider, the D3, trials of which were intended to provide information required to complete the powered machine, D4, which was under construction at Farnborough.

The glider proved quite promising at first, with a good number of short flights being made by Lt Gibbs on the very first day of the trials. However, later efforts were less successful, being hampered by the roughness of the terrain and the turbulence of the wind. As a consequence, the party appears to have spent a considerable amount of time roaming over a wide area, seeking a location which offered more favourable operating conditions, but

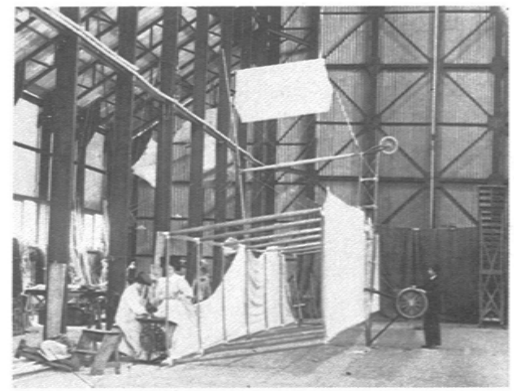
without success.

At the end of the month Dunne left Gibbs in charge of the group testing the glider in the hills while he, together with a few assistants, returned to Blair Atholl itself to begin erecting the powered D4, which had by then arrived from Farnborough. This operation appears to have been extremely difficult, especially at a distance of some 500 miles from the Balloon Factory's workshops. Problems with warped timber and inadequate tools delayed completion of the aeroplane until the middle of November 1908, by which time Capt Carden had come up to supervise the installation of the engine and to take charge of the testing.

Flight trials started on 15 November, with Gibbs at the controls, but difficulties with the undercarriage caused an immediate halt. Ground runs, interspersed with engine malfunctions, occupied the remainder of the month, and the first take-off, covering a distance of about thirty feet, did not occur until 4 December. Two days later Carden had to return to Farnborough, and the tests continued in his absence, more short hops being achieved despite the lack of his skills with the engine. On 10 December Gibbs managed a flight of 120 feet, and on this note of minor triumph the trials were ended.

In common with many of its contemporaries, the Dunne D4 appears to have been rather underpowered, especially in view of its very heavy undercarriage, and the final acceptance of this shortcoming may well have been the reason for the seemingly premature ending of the tests. Alternatively, it is equally possible that the Dunne party was defeated by the weather, for winters in the Scottish highlands can be very severe. In any event, the test flights of the D3 and D4 seemed to uphold Dunne's theories regarding stability, even if his designs of aeroplanes and their control systems needed further development.

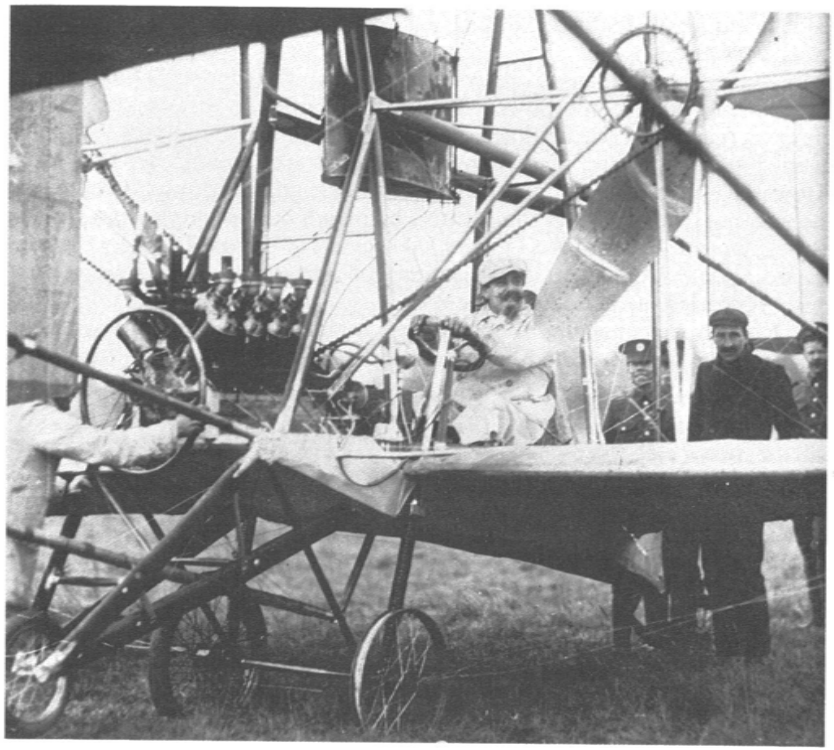
S F Cody, meanwhile, following his period of involvement with the airship *Nulli Secundus*, had been away demonstrating his man-lifting kites



Sewing the fabric covering on to the mainplanes of British Army Aeroplane No 1 inside the original airship shed, with S F Cody keeping a watchful eye on the workmanship.
(Royal Aerospace Establishment)

to the Royal Navy, in the unfulfilled hope that they, too, would decide to purchase his system. He returned to Farnborough on 6 September 1908 to supervise completion of the machine which had been officially titled British Army Aeroplane No 1, but which showed the unmistakable hand of Cody in its design. The construction of this aeroplane had been proceeding sporadically since the previous November, in whatever time Cody had been able to spare from his numerous other duties. Now, perhaps spurred on by the purchase of a replacement 50hp Antoinette engine, and by a desire to beat Dunne, work on the aeroplane progressed rapidly, and by the 19 September it was sufficiently complete to be taken out for engine tests. Taxying trials, made two days later in a clearing near the Factory, revealed that the machine was nose heavy, but ended suddenly when a wingtip struck a post and was slightly damaged. This was soon repaired, and ground trials recommenced on the 24th, this time on Laffan's Plain where there was far more space, although the surface was poorer.

At one point, during further taxying trials on 30 September, Cody

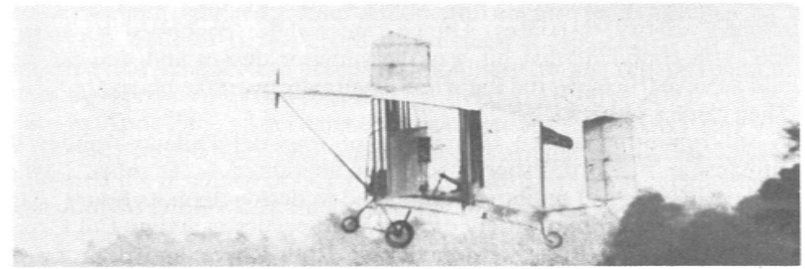


S F Cody at the controls of British Army Aeroplane No 1. The photograph was taken in September or early October 1908, and was almost certainly posed for the benefit of the press, as one wheel is still without a tyre. Note the crossed chain drive to the propeller on the port side.

became aware of a brief pause in the vibration, and a subsequent examination of the machine's wheel tracks revealed that it had left the ground for a short distance. Although Cody dismissed this as 'only a jump', it was a genuine take-off and a positive step towards powered flight. Unfortunately further tests had to be postponed, as Cody was required to return to Portsmouth to conclude his kiting demonstrations for the Royal Navy. He returned to Farnborough in time to resume trials with the aeroplane on 14 October, some modifications intended to reduce drag and improve the pilots' view having been carried out during his absence. On this occasion two more short hops were made, each of about fifty yards, at a height of eight to ten feet.

On 16 October British Army Aeroplane No 1 was taken out again, and, while taxying at speed in order to climb a slope, Cody made yet another 'jump' of some seventy-five yards. Then, starting near to the south-eastern corner of Farnborough Common, close to the Swan Inn plateau, Cody set off towards the north-west and, after a ground run of some sixty yards, took off and flew at a height of approximately thirty feet until he was forced to turn to avoid a clump of trees. During this manoeuvre the tip of the port wing made contact with the ground and the flight ended in a crash, with considerable damage to the port wings. Fortunately, Cody was completely unhurt.

This flight, now officially recognised as the first sustained and controlled powered aeroplane flight in Great Britain, covered more than a quarter of a mile and lasted twenty-seven seconds (an airspeed of 35mph).



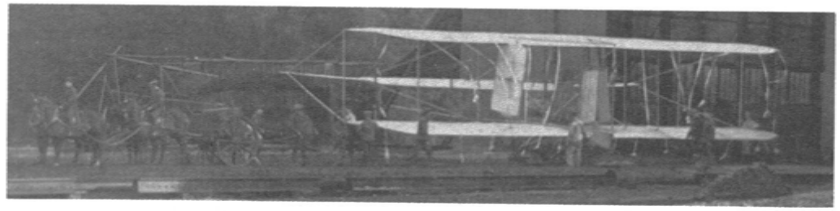
British Army Aeroplane No 1 making the first aeroplane flight in England, on 16 October 1908.
(via John Bagley)

The next day's edition of *The Times* carried a full account of the flight under the headline 'The Army Aeroplane—Accident at Farnborough', and totally ignored the real significance of the event. Thus were Cody and the Balloon Factory deprived of the public recognition their joint achievement deserved.

Capper's report to Whitehall, written on the day of the flight, was equally unenthusiastic, concentrating upon the accident and the resultant damage rather than upon the significance of the flight itself. It ended with the words, 'I do not propose to abandon trials of this machine'. Perhaps Capper was a

little disappointed that his protégé, Lt Dunne, had not been the first to fly. Whatever his reasons for this unnecessarily negative attitude, Capper's report, coupled with his suggestion that more space was required for aeroplane experiments than existed at Farnborough, was the first step towards a conclusion which must have been the last thing he wanted.

British Army Aeroplane No 1 was repaired, a number of small modifications being incorporated at the same time, and flight trials resumed in January 1909, this time on the slightly less restricted ground of nearby Laffan's Plain. These trials included the attachment of numerous streamers to various points on the machine's surfaces to show the airflow.



British Army Aeroplane No 1 emerges from the Airship Shed on 20 January 1909, after rebuilding. The streamers are to show the path of the airflow over the machine. Note the folding tailbooms, designed to facilitate storage.

Cody, an accomplished horseman, quickly developed his piloting skills, making numerous flights, often close to the ground, to explore the machine's control responses. Dunne, meanwhile, continued his experiments, still confident that his was the superior design and that he, too, would achieve true powered flight and eventually overtake his rival.

Then came a setback.

A subcommittee of the Committee of Imperial Defence, under the chairmanship of Lord Esher, had been appointed in October 1908 to consider all aspects of military aviation and to decide upon its future. After receiving reports from a variety of interested parties including Col Capper and the Hon C S Rolls (co-founder of Rolls-Royce and a prominent balloonist and pioneer aviator), and considering the opinions of representatives of both the Army and Navy as to their probable future requirements, the committee finally reached the conclusion that the expenditure to date of some £2,500 (a figure which did not include salaries or establishment cost) had been too great for the results obtained. Consideration was given to the gradual but now increasing emergence of commercial aeroplane manufacturers, and it was concluded that it might be more practicable simply to purchase aeroplanes built by the 'trade' which appeared to be suitable for military purposes. Rolls even offered the Army the occasional use of his own Wright Flyer, built under licence in England by Short Brothers, with himself as pilot. This offer was accepted. It was further concluded that airships, which still seemed better adapted to military needs, should continue to be developed by the Balloon Factory, and that, in addition, the Navy should be allowed to develop its own rigid airship.

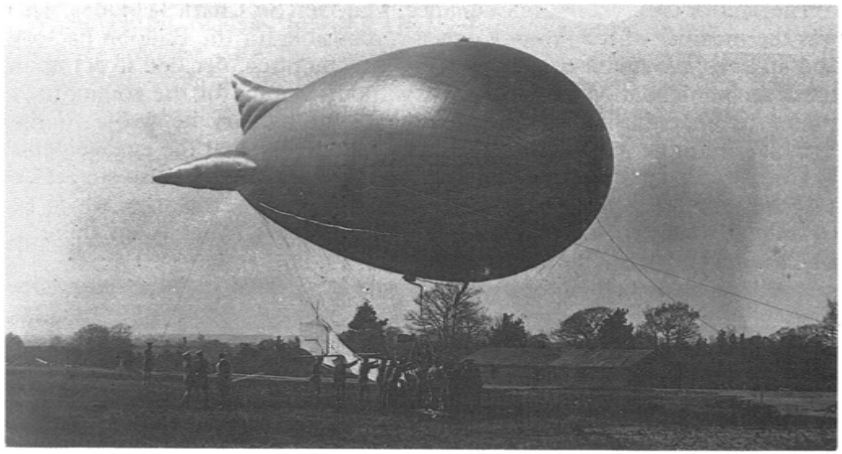
The Master General of the Ordnance, Maj-Gen Sir Charles Haddes, who was the member of the Army Council responsible for the Balloon Factory and an *ex officio* member of Lord Esher's Committee, decided to act upon these recommendations immediately, without waiting for the committee's report to be published. Consequently, on 29 January he wrote to the Secretary of State for War, R B Haldane, proposing that the engagements of Cody and Dunne be terminated as soon as possible. He also suggested that they should be allowed to keep their respective aeroplanes, which he considered to be virtually worthless, but not the engines fitted thereto, which would be of use for the airships.

Probably because they represented a considerable financial saving, these proposals were readily accepted. Dunne was accordingly informed that his services would not be required after 31 March 1909, after which date he would revert to the sick list, on half pay, his health still being too frail for general duties. Cody, who was a civilian under contract, was to be retained as Chief Kite Instructor until 30 September, when his current contract would expire, but was to be allowed, and even encouraged, to leave earlier. Since he had quite willingly given up his stage career and dispensed with his own kite-building facilities when he entered Government employ, thereby depriving himself of all previous sources of income, he was thus to be left without any means of support. Consequently he appealed against this rather unfeeling decision, was given a fair hearing, and was eventually—and rather surprisingly—given permission to erect a shed for his aeroplane on Laffan's Plain and to continue his flying experiments there. He was also allowed to take with him, on loan, the Antoinette engine then installed in the aeroplane, until he could afford to purchase a replacement of his own, provided that he agreed to accept responsibility for any repairs found to be necessary upon its eventual return to the Balloon Factory.

So, by April 1909, all aeroplane experiments at the Balloon Factory came to an end, just as they had reached the threshold of success. Just how ill-advised the dismissal of Cody and Dunne had been was highlighted only three months later, when, on 25 July, the Frenchman Louis Blériot flew his No XI monoplane across the English Channel to land at Dover, demonstrating the practicability of the aeroplane and giving rise to the alarmed cry that Britain was 'no longer an island'.

Capper's opinion is not recorded, but he accepted the decisions with true military aplomb, and applied his energy to the only avenue left open to him, the Factory's airship development programme. Despite these upheavals he was able, on 11 May, to launch a new non-rigid of only 21,000 cu ft capacity. This vessel, appropriately named *Baby*, had a streamlined goldbeater's skin envelope (a result of Carden's windtunnel research), and was powered by the two 12hp Buchet engines which had already served in the Cody Power Kite and Dunne D1. She proved to be capable of 20mph, carrying a crew of two, although she had limited endurance. The provision of a ballonet in what was, in practice, an expandable envelope, made it difficult to achieve the differential pressure necessary to maintain the required tautness of the envelope, and proved to be a constant source of irritation to *Baby's* crew.

During a series of test flights which took place throughout May and June,



The airship *Baby* as originally built. The location is believed to be Farnborough Common.

various forms of control surface were tried. Unfortunately sufficient time was not allowed to test one type's effect fully before another set was substituted, leading to rather confused and inconclusive results to her trials. The Buchet engines also proved troublesome, and during July were replaced by a single REP which delivered a fairly reliable 25hp and drove twin propellers mounted on outriggers, a system which had already been proved on *Nulli Secundus*. Thus powered, she was found to be no easier to control, and it eventually became apparent that her envelope, although it was of adequate streamline shape, was too squat for effective stability to be possible either laterally or in pitch. Despite these shortcomings, *Baby* appears to have been regarded as sufficiently successful to justify the design and construction of a larger craft of broadly similar configuration.

The Balloon Factory's status was still far from being resolved, and throughout the first half of 1909 its work was carried out against a background of continued investigations and interference. In May the Prime Minister, H H Asquith, had invited a number of eminent scientists to join with Naval and Military representatives in forming an Advisory Committee for Aeronautics under the chairmanship of Lord Rayleigh, then acknowledged as a great experimental physicist. Among those who accepted were Dr R T Glazebrook, Director of the National Physical Laboratory, and F W Lanchester, well known for his research into motion in fluids.

This distinguished body clearly considered a tour of HM Balloon Factory to be of great importance, and such a visit was made on 5 July. As the aeroplanes were long gone and the only complete airship, *Baby*, was being fitted with a replacement engine, there was little for them to see. Nonetheless they evidently saw enough to realise that, if the Factory was going to make any real advancement in aeronautical science, its work needed to be conducted in a far more systematic way than the trial-and-error method which had hitherto sufficed, and reported accordingly.

Quickly acting upon the Committee's recommendations, R B Haldane, whose responsibility the Factory was, announced in Parliament at the beginning of August that it had been found prudent to divorce 'instruction' from 'construction', and that the Balloon Factory and Balloon School were therefore again to be separated. The latter was to remain a military unit under the command of Capper, while the Factory was to become a civilian establishment under the control of a new superintendent who would, in turn, be directly responsible to the Master General of Ordnance (department MA3) at the War Office.

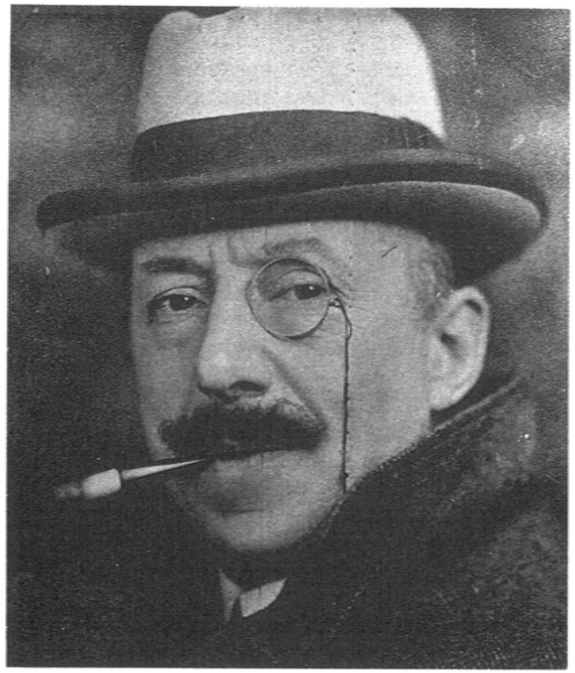
Haldane also told Parliament that, while he did not mean to say that the Government should not experiment, he thought it vital that the mass of scattered information available from various sources should be investigated in a scientific and orderly fashion. He also announced that the War Office was authorised to spend £36,000 on aviation that year (compared with £5,270 the previous year), and that £6,000 was to be spent upon a new airship shed at Farnborough. The workshops were to be extended, with a standard-gauge railway system inside, and departments were to be established for research into chemistry, physics, metallurgy and wireless.

Thus the organisation founded by Col Templer had, since his official retirement only three years previously, been changed beyond all recognition.

A new era begins

The man chosen to be the new Superintendent was Mervyn Joseph Pius O'Gorman, who took up his appointment on 19 October 1909 on a seven-year contract, initially on a part-time basis. It is not entirely clear whether this rather curious arrangement was intended to allow him to maintain his established links with other fields of industry, or to give him time in which to conclude his existing involvements. Nevertheless, in return for three days' service each week he was to receive an annual salary of £950. This was a seemingly handsome remuneration, especially for the head of an organisation which at that time had a total staff of only about a hundred, but, in reality, it amounted to little more than the total of salary and allowances which had been paid to Capper.

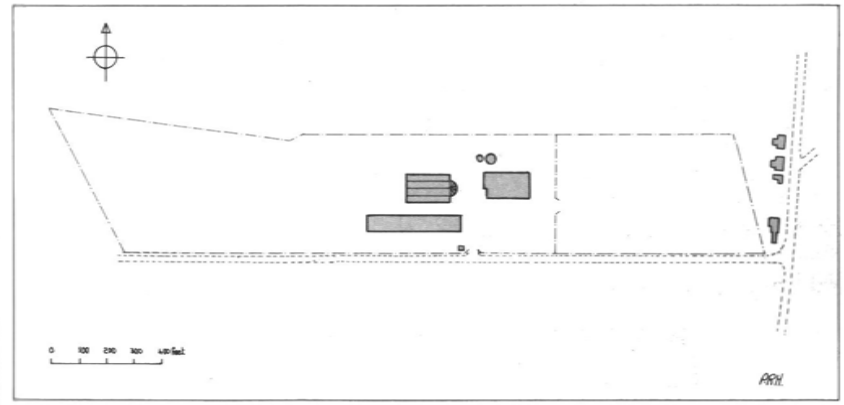
O'Gorman, who was then aged 38, was a well respected mechanical engineer. Since taking an engineering degree at Trinity College, Dublin, followed by postgraduate study at the City and Guilds Institute in London, he had been working largely in the automobile industry as a partner in Swinburne, O'Gorman and Baillee, consultant engineers. He had also studied physics and French, the latter to a standard of proficiency to have



Mervyn Joseph Pius O'Gorman, Factory Superintendent from 1909 to 1916.

enabled him to have worked, for a time, in France.

Of obvious Irish descent, 'O'G', as he was popularly known, was blessed with a brisk, flambuoyant manner and a disarming wit. He affected a gold-rimmed monocle and a long cigarette holder, constantly smoking Turkish cigarettes whose aroma seemed to fill the entire factory. His appointment had been proposed by Lord Rayleigh (a president of the Royal Society, and, later, the first president of the Advisory Committee for Aeronautics) and approved by Sir Charles Hadden, Master General of Ordnance, to whom, as Factory Superintendent (he would have preferred the title of Director), he would ultimately be responsible.



HM BALLOON FACTORY, 1909

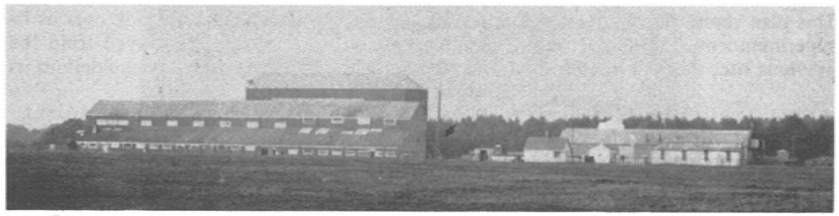
This plan shows the site as it was at the end of 1909, when O'Gorman took over as its superintendent. The only buildings are the balloon shed, which was moved from the previous site, the new airship shed, and the workshop block, with the gas holders to its north.

Immediately upon his appointment O'Gorman became, *ex officio*, a member of the Advisory Committee for Aeronautics, replacing Capper. He quickly began to make his presence felt. He established that the rôle of HM Balloon Factory was to conduct experiments, research and tests; to prepare specifications; to analyse the results of tests upon trial designs, and to reply to scientific queries, proposals and theories which the civil and military authorities, or any official body, put to it. To assist in meeting these objectives it was intended that the Balloon Factory would co-operate closely with the National Physical Laboratory, whose director, Dr Richard Glazebrook, also served upon the Advisory Committee. One example of this co-operation was the Balloon Factory's continued use of the recently completed windtunnel at the NPL. This was considered to be better than the Farnborough tunnel, because the fan was at the outlet end and the airstream was therefore sucked, rather than blown, past the test position, giving a far smoother airflow, albeit at a fairly restricted maximum velocity.

By accident or artifice the origin of the 'trial designs' mentioned in the description of the Factory's rôle had not been defined, but O'Gorman

appears, even then, to have held the opinion that it would be advantageous for the Factory to be allowed to continue building its own experimental aeroplanes, thereby proving the results of its various research projects, testing theories, and furthering the development of military aviation. Although this was currently outside the Factory's allotted scope, O'Gorman was content to bide his time, confident that the restriction would eventually be rescinded or could be circumvented. It was not O'Gorman's wish that the Factory should undertake volume production, to which the Farnborough workshops were wholly unsuited, but merely that it could build prototype or research aircraft, of whichever designs seemed the most promising. To this end the Factory's facilities were intended to provide the most versatile 'jobbing shop' that it was possible to achieve, and all expansion was carried out to that end. However, although work was already in hand to enlarge the workshops, this would not be completed for some time. At the time of O'Gorman's appointment the Factory consisted only of the workshop block (80ft × 50ft) brought from Aldershot, the airship shed, which had been built in 1906, and the shed in which balloons were normally constructed.

O'Gorman soon realised that, however willing and dedicated his small staff may be, it was deficient in certain specialised skills. For example, virtually all drawing was done by Stanley W Hiscocks, who had originally been engaged by Capper to detail airship components for fabrication. In the past many components had simply been 'designed' in the workshop, without any drawing being prepared. This approach was clearly totally out of place in a properly-run scientific research establishment of the kind that O'Gorman and his Whitehall masters wanted the Balloon Factory to become.

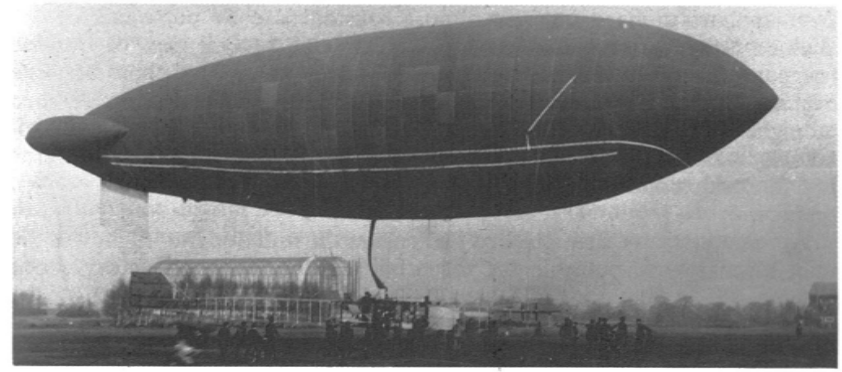


A view of the Balloon Factory from Farnborough Common in 1909. The mast at the rear of the Airship Shed is thought to have been used to support the cable along which Cody's Power Kite was 'flown'.
(National Army Museum)

Consequently, while visiting the Daimler Factory he discussed the matter with Frederick Lanchester, who was currently engaged there and with whom he was well acquainted, seeking his opinion as to possible candidates for the proposed new post of 'Engineer—Design'. Acting upon the advice received, O'Gorman offered the position to Frederick Michael Green, who was then on the engine design staff at Daimler. He quickly accepted, joining the Farnborough staff in January 1910. This was just one of many occasions on which O'Gorman employed the recruitment technique now known as

'head-hunting'. He frequently sought staff from the established factories in the industrial midlands, but largely ignored the growing aeroplane industry, whose standards of workmanship he frequently considered 'too low'. Later, when the staff of the Factory became too numerous for O'Gorman to know them all, similar methods appear to have been practised by the managers, supervisors and heads of department responsible for recruitment.

Another early appointment, that of the new Assistant Superintendent, was made by less involved means, as the candidate chosen, Lt Theodore John Ridge, was already serving in the Balloon Sections.



Gamma is prepared for its first flight, on 12 February 1910, with the new airship shed under construction in the background.
(British Balloon Museum and Library)

Throughout all these changes, work on projects initiated by Capper before his retirement was still proceeding, and on 19 February the new non-rigid airship *Gamma* was launched. Incorporating lessons learned from the trials of *Baby*, the new vessel was longer, relative to its girth, with a capacity of 75,000 cu ft of hydrogen, her rubberised cotton envelope having been designed at Farnborough but manufactured by a contractor in France. Powered, initially, by an eight-cylinder Green engine, nominally of 80hp, *Gamma* could carry a crew of up to five and, after various modifications to the design of the tail surfaces, eventually achieved a speed of 32mph. The propellers could be swivelled about their transverse axis, thereby providing vertical thrust to facilitate rising and descent. This feature not only made operation from small spaces much safer, but also reduced the airship's dependence upon maintaining neutral buoyancy, since she could, to some extent, be driven up or down by the force of her propellers, thus helping to conserve hydrogen or reduce the quantity of ballast necessary.

Following her maiden flight on 12 February, with Capper in command at O'Gorman's invitation, *Gamma* undertook a lengthy programme of trials, thus allowing *Baby* to take her place in the workshops. The envelope of the diminutive airship was divided at the point of greatest diameter and an additional section, twenty feet long, was inserted. This bold and resourceful

modification increased her displacement volume to 35,000 cu ft, with a consequent increase in useful lift and a beneficial effect upon her directional and horizontal stability, eliminating the problem which had beset her in previous trials. In fact, she was so improved as to be almost a different craft, and she was re-christened *Beta*. It was intended that the name *Alpha* should be applied retrospectively to the first Farnborough airship, but the original name, *Nulli Secundus*, was already far too well established in people's minds to be easily superseded. (As the airship was already dismantled, any change of name would achieve little or nothing).

Following the satisfactory conclusion of her trials, which started in May, *Beta* appears to have been in almost constant use by personnel of the Balloon School throughout the summer, making several trips to London (perhaps demonstrating an unexpressed desire to lay the ghost of *Nulli Secundus* ignominy). One such trip to the capital is described as having been 'at night', but, as this was on 3 June, the question may arise as to how dark it actually was during the flight. On another occasion she achieved the round trip to London and back, covering a distance of about 100 miles, in just 4hr 4min.

Among the many distinguished passengers she initiated into flight was the man ultimately responsible for the affairs of the Balloon Factory, Lord Haldane, then Secretary of State for War (although the ascent had to be delayed while he was persuaded to exchange his top hat for more suitable, but less formal, headgear).

The 1910/11 Army estimates again allowed for a capital expenditure of £30,000 at the Balloon Factory, and permitted the purchase and erection of an electrolysis plant (£2,278) for the production of hydrogen, together with new gas holders (£2,366) and a compressor plant (£946) so that cylinders could be filled for use in the field. The electrolysis plant was purchased from the Oerlikon Company of Switzerland, but the remainder of the equipment was designed and produced locally. Electrolysis produced pure hydrogen in fairly large quantities by passing an electric current through water and thereby reducing it to its component elements, hydrogen and oxygen. A small quantity of sulphuric acid was normally added to the water to serve as a catalyst.

Other items of capital expenditure included the continuing extension of the workshop blocks and the construction of two new airship sheds (at a cost of £12,340).

In September 1910 three aeroplanes took part for the first time in the military manoeuvres held on Salisbury Plain. Of these, two were Bristol biplanes loaned to the Army by the manufacturer, one flown by Capt Bertram Dickson and the second by the famous actor and pioneer airman Robert Loraine. The third machine was a Farman biplane piloted by its owner, Lt Gibbs, who had been at the controls of Dunne's powered aeroplanes for their trials in Scotland in previous years, and who had obviously developed a passion for aviation. During these manoeuvres Loraine made the first air-to-ground wireless transmissions, at ranges of up to a mile, although they were one-way only. All in all, the aeroplanes' participation was considered to have been a great success, and was partly

instrumental in bringing about a number of far-reaching changes in military aviation, each announced in turn by the War Office.

The first change was the appointment of Maj Sir Alexander Bannerman to replace Capper as commandant of the Balloon School. Capper accepted the promotion for which he was due and returned to more conventional soldiering, eventually rising to the rank of major general and commanding a Division during the First World War.

Next, on 10 October, it was announced that, '. . . with a view to meeting army requirements consequent on recent developments in aerial service, it has been decided to enlarge the scope of the work hitherto carried out at the Balloon School, Farnborough, in affording opportunities for aeroplaning as well as developing the training in the employment of dirigibles more fully than has hitherto been the case'.

Alone among contemporary aviation journals *The Aero*, which was then edited by C G Grey, chose to be singularly unimpressed by the announcement, describing the decision as 'more War Office folly'. The journal suggested that any area of country less suitable for aeroplaning than the Aldershot district had yet to be discovered, a comment which perhaps recalled the crash which concluded Cody's first aeroplane flight there, two years previously.

One week later it was further announced that the scope of the Balloon Factory was to be similarly enlarged, with the Factory being required to repair and maintain the Balloon School's aeroplanes, just as it had always cared for their balloons and kites. The difference was that, while the balloons and kites were also built by the Balloon Factory, the aeroplanes were to be obtained from outside sources. There was no suggestion that the Factory should once again be allowed to design and build its own aeroplanes. Presumably the Factory was expected to borrow aeroplanes from the Balloon School to conduct the experimental work now required of it. What O'Gorman thought of this situation is not recorded. This is perhaps fortunate, as his diary reveals that he already found sharing a site with the Balloon School a constant source of irritation. He makes repeated references to Sappers over whom he had no authority wandering through his workshops, and to their officers distracting his foremen.

The acquisition of aeroplanes began almost immediately, with the donation, to the Balloon School, of an outdated Wright biplane given by the Hon C S Rolls. This unwanted gift was installed in the airship hangar, where it took up valuable space, and was almost certainly never used. Orders were also placed for two French-built machines, a Farman pusher biplane and a Paulhan of unconventional design.

On 26 October 1910 a new, French-built airship arrived at Farnborough. She had been purchased for the nation at a cost of £25,000, the money having been raised by public subscription among the patriotic readers of the *Morning Post* newspaper. This craft had been built at Moisson, to the north-west of Paris, by MM Lebaudy Frères, who were well-known and respected airship manufacturers and had already supplied several airships to their own government. The new vessel was far larger than any British-built contemporary, her 353,000 cu ft envelope being fabricated from Hutchinson

The *Morning Post* airship en route to its disastrous arrival at Farnborough.
(via Paul S Leaman)

Balloon Cloth, a newly developed material which had already been subjected to stringent testing by the French Government research establishment at Chalais Meudon.

The airship's arrival was well publicised, especially by the *Morning Post*, and a large crowd gathered on Farnborough Common to watch her complete her journey of over 200 miles in 5½ hours, carrying a crew of seven including Sir Alexander Bannerman and the editor of the *Morning Post*. One of the newly completed sheds at the western end of the Factory compound had been planned specifically to provide accommodation for the new airship, but her builders had increased her overall height during construction without informing her intended owners of the change. Consequently, as she was being walked into the hangar, the top of her envelope snagged on a projecting bolt at the top of the doorway, and was gashed open. Her hydrogen escaped and she collapsed on top of the ground-handling party, many of whom suffered injury as a result.

The mishap was witnessed by Lord Roberts, one of a number of generals present. Seeing a soldier emerge from under the wreckage, bleeding profusely from numerous cuts and abrasions, Roberts asked him if he was hurt. The soldier, Corporal Edward Bolt, not recognising the general out of uniform, replied, 'Can't you see I am, you bloody fool?' An officer immediately ordered him to be placed under arrest for insubordination, but Roberts intervened, saying, 'No! I asked a silly question, and got the right answer.' However understanding the general might have been, O'Gorman, with his meticulous attention to detail, was clearly unimpressed by the whole affair. He remained of the opinion that the Balloon Factory should

produce its own designs, and work was put in hand on the production of the next airship, *Delta*, which was to be its largest yet. Meanwhile, another French airship, a Clement-Bayard which had been purchased secondhand by the War Office and had been flown to Wormwood Scrubs earlier in October, was deflated, dismantled and brought to Farnborough by road, an action which spoke volumes for its condition and airworthiness.

A chance meeting at the Olympia Motor Show, one day in November, between F M Green and Geoffrey de Havilland (who had spent the whole of that year developing an aeroplane of his own design) resulted in the latter making an approach to O'Gorman, seeking employment at the Balloon Factory. Following an interview at O'Gorman's fashionable Chelsea home, de Havilland was engaged as a designer, under Green's direction, and as a test pilot, for which duty he was to receive additional remuneration for each flight made. Frank Hearle, who had previously been employed as de Havilland's assistant, was offered a position as a mechanic, which he accepted. Hearle and de Havilland were to remain close throughout their lives, with Hearle eventually marrying de Havilland's sister, Ione.

De Havilland's Farman-type pusher biplane, which was powered by an engine which he had also designed, but which had been built by the Iris Motor Company, was purchased by the War Office for £400, subject to its creator demonstrating its ability to fly for one hour without adjustment or repair. Owing to the severity of the weather during 1911, there being a sharp frost throughout 14 January, the day chosen for the tests, de Havilland was allowed to land every twenty minutes to thaw out, thus completing the one-hour flight in three stages. However, he did fly continuously for over an hour soon after, justifying O'Gorman's faith in the aeroplane, which thus joined the growing assortment already at Farnborough.

Another addition was a damaged Blériot XII which had been operated at Larkhill, on Salisbury Plain, by a group of RE officers, and whose uncertain flying characteristics and frequent crashes had earned for it the nickname *Man-Killer*. While it had yet to live up to its name, its erstwhile pilots seemed pleased to be rid of it, pending its repair at Farnborough. One of them, Lt R A Cammell, bought a 70hp two-seater Blériot XXI of his own, thereby effectively replacing it.

Although the Factory's interests and investigations were turning towards aeroplanes with growing intensity, experiments with lighter-than-air craft continued with undiminished enthusiasm. On 27 January 1911 *Beta* took part in ground-to-air wireless experiments, using equipment designed and built at Farnborough by Capt H P T Lefroy, who had joined the Factory staff to take charge of wireless development. In all previous trials the transmitter had been carried aloft while the more bulky receiver had remained on the ground. Lefroy had now developed a lighter receiver which could be flown—although as yet only by an airship—to enable communication to take place in the reverse direction.

On 28 February it was announced that, with effect from 1 April, the Balloon School was to be renamed the Air Battalion, Royal Engineers, officially acknowledging that it was an operational unit whose activities

ranged far beyond mere ballooning. The unit was also to be expanded to a complement of 14 officers, 33 NCOs and 153 men, together with two buglers and 36 horses. Officers seeking to transfer to the Air Battalion from other units were required to be under thirty years of age and unmarried, with good eyesight and a weight of less than 160lb.

The air estimates proposed by the Chancellor of the Exchequer, David Lloyd George, during his 1911 budget speech included sums of £85,000 to be spent on the acquisition and operation of airships and aeroplanes, and £28,000 for additional buildings. These sums, although laughably insignificant when compared with today's defence spending, were a dramatic increase on the allocations of only a few years earlier, and reflected the increased importance being attached to aviation by a slowly awakening Parliament.

Among the buildings upon which the £28,000 was to be spent were two hangars for the Air Battalion, finally ending its need to share space with the Balloon Factory, a constant irritation to O'Gorman. These hangars, or 'sheds', as it was officially decided they would be called, were of a design which was to become standardised for such buildings. They later became famous as the 'Black Sheds' which marked the north-eastern end of the modern Farnborough runway. The northernmost shed was demolished during the 1960s, but the other survives to this day, although it is currently (1989) in a rather dilapidated condition. The small two-storey building which was the Air Battalion's first headquarters also dates from this period. This, too, has survived, and part of it currently houses the RAE's own private museum. By the erection of these buildings the Farnborough establishment expanded beyond the fenced twenty-two acres into which it had moved in 1905/6, this being just one of the many stages by which what is now the RAE gradually took over the 1,100 acres it presently occupies.

O'Gorman regularly made representations to the War Office for the Farnborough site to be cleared of trees to make it a more effective aerodrome, and for a strip to be cleared from Farnborough Common to nearby Laffan's Plain to give a reasonable area for testing, but this was clearly too large an undertaking for immediate assent.

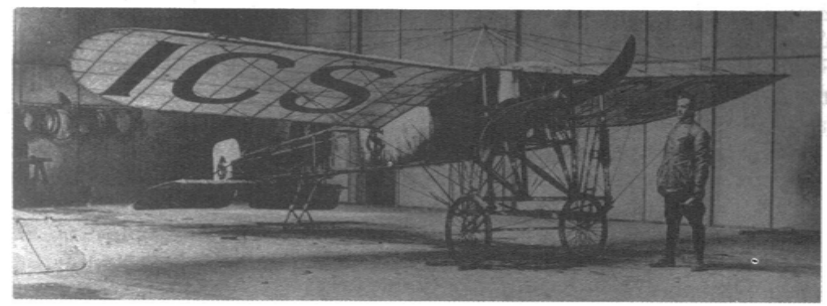
Other building work carried out at this time included the extension of the original (1906) airship shed, which was too small to accommodate any but the smallest vessels, and was thereafter always referred to as the Beta Shed. (It was demolished in 1960, and the site is now the Beta Car Park). The extension, which almost doubled its length to some 300 feet so that *Delta* could be safely housed therein, cost £6,750, a figure which exceeded the original cost of its construction. A 'portable' airship shed, comprising a canvas-covered steel frame, was erected alongside the newer airship sheds at the western end of the site at a cost of only £850.

On 8 March 1911 O'Gorman demonstrated the nature of his approach to aeronautical research by the presentation to the Institution of Automobile Engineers (of which he was a prominent member) of a paper entitled 'Problems Relating to Aircraft'. He asserted that aeroplanes and dirigible balloons (airships) each had certain advantages, and that: 'Neither can be described as a generally preferable way of obtaining the objects of flight,

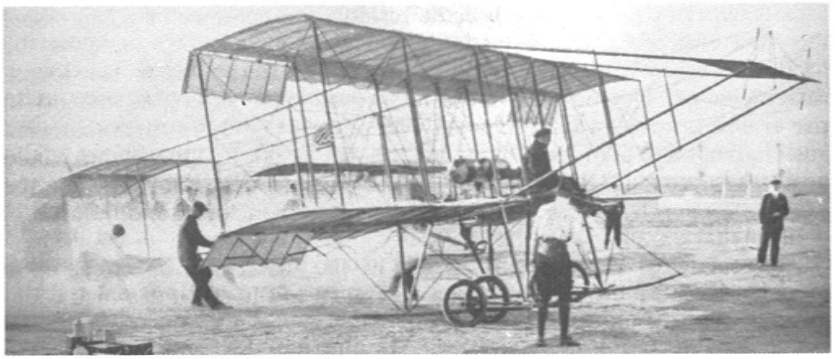
each is superior in obtaining specific results'. He continued by expressing the view that each would be improved if endowed with some of the properties of the other. The disadvantages of the aeroplane he considered as being its need to come down should its motive power fail, its inability to rise or descend vertically or to hover over one spot, and the effect that wind gusts had upon its stability. On the other hand, he felt that the airship would be much improved if it did not lose gas, or become more buoyant when the sun shone upon it, and if it could be given increased speed and reduced in bulk, so that it could be handled on the ground by a few men.

Reference was made to the nature of the wind, and its effect upon aeroplanes, and much consideration was given to the stability which could result from the proper relationship between supporting planes and secondary, or stabilising, surfaces. To illustrate his points O'Gorman divided aeroplanes into various types or classes, according to their general configuration, and named each class after a pioneer of that type of machine:

The Santos-Dumont 14*bis*, which made the first powered flight in Europe and lent its name to O'Gorman's 'S'-Class canards.



O'Gorman designated all tractor machines 'B' Class after Blériot's famous cross-channel machines, which remained in production until about 1915.



The famous pioneer pilot Claude Grahame-White in a Farman pusher of the type which gave O'Gorman the designation 'F' Class for pusher designs.

'S' Class (Santos-Dumont)—Those whose main wings are preceded by a small plane which is more intensely loaded and succeeded by the propeller [Canards].
'B' Class (Blériot)—Those whose main wings are preceded by the propeller and followed by a smaller plane . . . which is loaded more lightly, if at all [Tractors].
'F' Class (Farman)—Those which have the main wings followed by a smaller plane more lightly loaded . . . but the propellers of which are placed between the main wings and the tail plane. [Pushers]

Although no one class showed overall superiority, the 'S' class was unique in automatically entering a dive when the engine stopped, a characteristic which was thought to offer greater safety, although the 'B' class was generally more stable. The paper also covered such diverse topics as the best streamline form for struts, the properties of various aerofoil sections, and the design of undercarriages. O'Gorman also suggested that aeroplanes could be tested by suspending them, inverted, and loading their wings with sand to simulate the load upon them in flight. He also recommended that the words 'pitch' and 'roll' should be 'earmarked' as meaning, respectively, longitudinal and lateral movements of a pendulous kind. He described the Factory's new tautness meter, which measured the tension in a wire without its needing to be cut or broken, such readings forming the basis of stress and factor-of-safety calculations.

This paper, which totalled almost 20,000 words, not only illustrated the range and quality of the research which had been conducted at the Balloon Factory in a relatively short space of time under the direction of its new Superintendent, but also highlighted the astuteness and agility of his thinking. His approach to the Factory's investigations is illustrated by the following statement, made during an address to the Aeronautical Society of Great Britain:

There is a strong presumption that advances could be made by attaining,

through experiments, the proper relative positions, magnitudes and shapes for planes and fins, their area, their warped portion, aspect ratio, thickness, flexibility and their distribution . . . various modifications suggest themselves, and records should be taken before and after effecting the change whilst leaving every other part of the machine unaltered.

The aeroplane class designations used by O'Gorman in the presentation of his paper had, in fact, already been adopted by the Factory, with the de Havilland-built pusher biplane becoming F.E.1—'F' Class Experimental No 1. These class designations, to which more were later added, often seem to cause confusion now, but they appear to have been readily understood by the Factory staff. They did, however, later encourage derision from the Factory's enemies, who suggested that it was an insult that service pilots should need to entrust their lives to machines which were still clearly designated 'Experimental', a superficial remark of the kind from which the Factory was never to be entirely free.

Aeroplanes again

As part of the general expansion of Britain's flying services and the shift towards heavier-than-air flight, it was announced, on 26 April 1911, that the Factory was again to be renamed, becoming His Majesty's Aircraft Factory. This change was made at the suggestion of Mervyn O'Gorman, the word 'Aircraft' comfortably encompassing both aeroplanes and airships. The establishment was usually referred to, both colloquially and in official correspondence, as the Army Aircraft Factory.

It was, however, still virtually a factory in name only, as its rôle was to remain unchanged as research and the maintenance of the Air Battalion's aircraft and equipment. Although the development of airships and experiments with the de Havilland-built F.E.1 continued, the design and construction of new aeroplanes remained outside its allotted sphere of activity. As is often the case when laying siege to an entrenched position, the solution lay not in a frontal assault, but in trickery, and, being anxious to conduct experiments with aeroplanes of different configurations, O'Gorman settled upon a subterfuge with which to bypass this tiresome restriction. To this end he requested permission to include, in the repair of the wrecked Blériot XII already at Farnborough, certain improvements and modifications so as to reconstruct the machine on more modern lines. Since the Master General of Ordnance was almost certainly ignorant of what was actually intended, and was influenced, no doubt, by O'Gorman's unaffected enthusiasm, such permission was eventually granted.

Logically enough the necessary design work was entrusted to Geoffrey de Havilland, who expected at least to retain the machine's existing tractor configuration, but O'Gorman was of the opinion that the canard, or 'S' class, possessed the greatest potential, and wanted the Factory to begin its experimental programme with an aeroplane of that type as soon as possible. Thus the drawings which were completed in April showed a machine bearing remarkably little resemblance to the original Blériot. In fact the 'reconstruction' would transform the tractor monoplane into a canard biplane, and it is doubtful whether much, or any, of the material from the wrecked machine could be re-used in the new one, with the obvious exception of its 60hp ENV 'F' engine.

Meanwhile, as the reconstruction work was taking place, the torn envelope of the Lebaudy *Morning Post* airship was repaired and re-inflated. The roof of its shed had been raised to accommodate it at a cost of £5,500. Finally, on 10 May, a trial flight was attempted. The walk-out from the shed was accomplished without difficulty, and the vessel took off quite satisfactorily, but, following a short flight, difficulties were experienced in manoeuvring and a hasty attempt was made to return to earth. The airship grew increasingly uncontrollable until, despite the ground party's considerable experience in handling non-rigid airships, she broke free and drifted away across Farnborough Common, driven by the freshening wind which had initiated the disaster. The errant airship then crossed the main

Aldershot/Farnborough road without gaining any height, and collapsed over a nearby dwelling, *Woodlands Cottage*, then the home of Captain and Lady Follett. One of the first to reach the scene was Mr McWade, the Factory's works manager, who had the presence of mind to turn off the petrol supply, stopping the engine and reducing the risk of fire.

The wreckage was returned to its shed, and there is no record of any further attempt to fly it, the War Office presumably adopting the very understandable attitude that, since it had cost them nothing to acquire, its destruction was no real loss and it would be imprudent to waste any more of the Air Battalion's (and the taxpayers') money on it. The Factory staff no doubt preferred to concentrate their energies, and still limited financial resources, upon craft of their own design or choosing.

Only two weeks later, and perhaps with this incident still fresh in his mind, O'Gorman suggested that he should patent a device for mooring airships in the open. His proposal was for an upright mast with a pivoting conical shelter through which a rope could be drawn to engage and anchor the airship's nose, and thus allow it to ride head to wind regardless of wind direction. Although no patent appears to have been taken out, the idea was adopted for general use. Such airship mooring masts were built, and continued in use until the demise of the airship in the 1930s.

In the cool, calm air at 5.30am on 7 June the reconstructed Blériot, now designated the S.E.1, was rolled out of the Farnborough workshops. The new machine had unstaggered biplane wings, the upper spaning 38ft and incorporating warping sections of wide chord and generous area. A covered nacelle, with a large elevator at its forward end, housed the pilot and the ENV engine which had been recovered from the wrecked Blériot. This was cooled by twin radiators placed flat on the cockpit sides. Twin rudders extended to the rear on booms, on either side of the pusher propeller.

The S.E.1's designer, Geoffrey de Havilland, now in his alternative rôle as the Factory's chief test pilot, took the controls for the first trials, but a wheel collapsed while the machine was still on the ground and the aircraft was returned to the workshops for repair. When it reappeared the following day, with its wheels repositioned to improve weight distribution, the machine took off successfully but was found to be far from satisfactory in the air. De Havilland therefore embarked upon a programme of development, constantly making modifications in an attempt to realise the potential which the canard layout was still thought to possess.

Later that same month the *Annual Report of the Advisory Committee for Aeronautics*, which was published by His Majesty's Stationery Office (HMSO), recorded that HM Aircraft Factory had conducted experiments and research upon a wide range of topics, which included:

The principle of dynamic stability in relation to the resistance of square plates.
The resistance and directional stability of airship models, with results applicable to aeroplanes.
The resistance of wires and ropes, including effects of vibration.
The Resistance of a honeycomb radiator.

Experiments on resistance of the spar girder used on the Paulhan Biplane.
Photographic study of the flow round plates and models in a stream of water.
Full scale and model propeller tests.
Fabric tests for permeability and strength.
Mechanical tests on Duralumin supplied by Vickers Ltd.
Meteorology and the rotary motion of air due to dustiness.

The results of these, and any other investigations conducted by the Factory and by the National Physical Laboratory, were also made available to the public and the trade as *Reports and Memoranda* (Rs & M) published by HMSO.

Drawing upon the results of experiments with de Havilland's F.E.1 and the S.E.1, O'Gorman was able to prepare a formula for the design of the 'B' class (tractor) machine which would logically form the next step in the Factory's research programme. He stipulated that the following points would be desirable:

1 Lateral control is to be obtained by warping a very large portion of both top and bottom planes, instead of warping a small portion. This is both more powerful and more efficient.

2 A new form of landing chassis to be designed, with adequate provision for absorbing vertical shocks by means of oil buffers and pneumatic absorbers.

3 Provision to be made for steering the machine on the ground at slow speeds by means of a swivelling back skid placed under the tail (this facilitates landing in a restricted area).

4 The motor and propeller to be placed in front of the planes to give the pilot a better chance in case of a bad smash. The pilot is raised sufficiently above the bottom plane so that he gets a good view of the ground over the front edge of the bottom plane. This is inferior to the view in the S.E.1, but at least as good as any other aeroplane with the engine in front.

5 The main surfaces are to be placed well in front of the machine and the stabilising surfaces at the rear set at a considerably smaller angle. This ensures fore-and-aft stability, but I incline to retain some curvature in the upper surface of the tail as giving a better riding moment.

6 The rudder and covered body will, I think, ensure sufficient directional stability. It is a matter of trial whether an extra vertical fin is to be fitted, and in any case this is very easy to do.

7 It is proposed to use a small amount of dihedral angle between the planes, probably 178°, i.e. 1° rise on each half plane.

8 The section of the planes used in the new machine will not be dissimilar to those of the S.E.1.

9 The general construction of the machine will be improved considerably in detail, particularly with regard to the planes. Stream-lined section struts are being used, also the main stay wires will be swaged to a streamline section. Every effort is being made to reduce head resistance as much as possible.

In May 1911 the Duke of Westminster donated a Voisin pusher of outmoded design to the War Office for use by the Army. Following a crash, this aeroplane arrived at Farnborough for repair on 11 July. It was duly examined so that its potential could be assessed, and on 1 August O'Gorman wrote to his Whitehall superiors, pointing out that the wood and fabric of the wings needed to be replaced and that the control system differed to that employed in other machines. He therefore requested permission to fit certain wings and struts that he claimed to have in stock, and to alter the control system so that it could be flown by anyone familiar with the Farman. Permission was granted on 12 August, effectively giving the Factory an opportunity to 'reconstruct' the wreck and produce the tractor biplane outlined by O'Gorman, the drawing work again being carried out under de Havilland's direction. Indeed, some phrasing in the design brief suggests that preliminary layouts at least had been completed by the time it was written. When the new machine finally emerged, towards the end of the year, not all of O'Gorman's suggestions had actually been incorporated into its design, but most, including an oleo undercarriage and streamlined bracing wires, were to be introduced during its development.

Geoffrey de Havilland was kept busy that summer, acting as test pilot and designer in the development of the S.E.1, continuing experiments with the F.E.1, and masterminding the design of the new tractor type, the B.E.1. The Factory's drawing office had already expanded considerably, and Sam Hiscocks, its original occupant, was now chief draughtsman. Among the new recruits to whom detail work on the B.E.1 was entrusted was a young designer later to make a name for himself, H P Folland, who had served an apprenticeship at the Lanchester Motor Company and worked for Daimler before joining the Factory.

On 16 August the Farnborough fleet was joined by a new pusher design, the F.E.2. A wholly new machine, its existence was explained away by declaring it to be a rebuild of the F.E.1, although the latter had been flying the previous day with the Factory's Assistant Superintendent, Lt Ridge, at the controls, and had sustained damage to its undercarriage and one wing when an engine failure necessitated a forced landing. This accident was, in a way, fortuitous, for it ruled out any possibility that the F.E.1 and F.E.2, which the War Office seems to have believed were one and the same, might be observed flying together.

The new machine, the first of several which were to be given the designation F.E.2, had a simple, covered nacelle housing its tandem cockpits and the 50hp Gnome engine which drove its pusher propeller. The wing construction was similar to that of the F.E.1, which added credibility to the 'rebuild' cover story, but the control and stabilising surfaces were to a completely new design, the forward elevator of the earlier design having been eliminated.

De Havilland, newly returned from his annual holiday, took the F.E.2 out at 4.30pm only to suffer engine failure, owing to a broken piston, after travelling only fifty yards. It says much for the efficiency of the Factory's workshops that he was able to take it up for its first flight at 6.30am on the 18th, effectively just one working day later.

TO THE GLORY OF GOD
THEODORE JOHN RIDGE
WHO SERVED AS A PRIVATE IN
AND WHO WAS LATE A LIEUTENANT IN THE LONDON BALLOON CORPS
HE LOST HIS LIFE ON AUGUST 1911 IN THE 30TH YEAR OF
HIS AGE, ON FARNBOROUGH COMMON, IN AN ACCIDENT
TO AN AEROPLANE OF THE ROYAL ARMY.
THIS TABLET IS ERECTED BY COMRADES OF THE

A memorial plaque to Lt T J Ridge, who was killed in the S.E.1. The plaque is now in the British Balloon Museum collection, but its original location is not known.

A great tragedy occurred later the same day, when Ridge took up the S.E.1 for the first time, against the advice of de Havilland and Green. He was a very inexperienced pilot, having only just obtained his *brevet*, and, despite continued development work, the machine's rudder control was still unsatisfactory. As he attempted a tight turn to avoid an obstruction, the machine sideslipped and crashed. Ridge was so badly injured in the crash that he died, in hospital, later the same day. The Coroner's inquest believed it to have been a result of what is today known as 'pilot error', and returned a verdict of death by misadventure, so the Blériot from which the S.E.1 had allegedly been reconstructed finally lived up to its sadly prophetic nickname of *Man-Killer*. The machine was not repaired, and the canard layout, which had not lived up to expectations, was abandoned, leaving the Factory staff shocked by the unfortunate and almost certainly unnecessary death of a colleague.

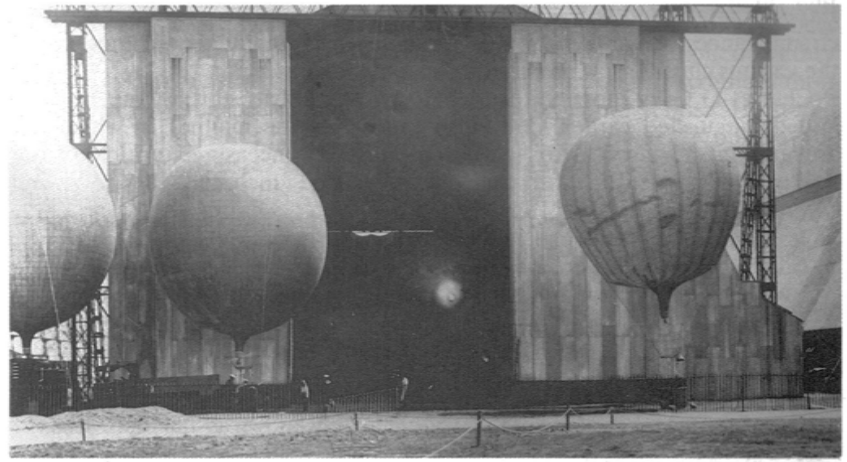
Soon thereafter O'Gorman sought, but could not obtain, permission to exclude the public from Farnborough Common. He had to be content with erecting public notices to the effect that the area was closed whenever flying was in progress, this being denoted by hoisting red flags.

S Heckstall-Smith was appointed Assistant Superintendent after a decent interval had elapsed following Ridge's funeral.

The airships *Beta* and *Gamma*, which had been in store since the previous year, were reinflated for the summer. *Beta's* envelope, after constant use and exposure to the weather, proved rather troublesome, leaking hydrogen continually and requiring repeated attention. *Gamma* was now powered by

two water-cooled, 45hp horizontally-opposed four-cylinder engines, built by the Iris Motor Company to the design developed by Geoffrey de Havilland to power his original aeroplane. In this form she proved capable of the slightly improved speed of 34mph. After fairly brief airworthiness trials to check her rigging and trim, she took part in that year's military manoeuvres. In service she became known, not without some affection, as the 'Yellow Peril', a sobriquet only partly attributable to the colour of her envelope, as a slight directional instability made her rather tricky to steer.

On 22 August *Gamma* completed the trip down to Salisbury Plain, the venue for the manoeuvres, where a temporary mooring mast had been erected to receive her. The fifty-mile journey was completed in ninety minutes against the prevailing south-west wind, and was accomplished without apparent difficulty. *Flight* reported her achievement, but commented upon the presence in her crew of a civilian mechanic, Mr H Moseley, who was presumably a Factory employee and who was in charge of her motors, and asked, rhetorically, why the job was not entrusted to a Sapper. The incident does, however, serve to demonstrate the degree to which operation of the Farnborough airship appears to have relied upon the co-operation between the Air Battalion and the Factory, the latter being a civilian organisation.



Spherical balloons outside the western end of the new airship sheds. The airship seen inside is *Delta*.
(JM Bruce/GS Leslie)

A few weeks later the Factory's newest airship, the 175,000 cu ft *Delta*, was completed, with an envelope of Continental rubber-proofed fabric and powered by two White and Poppe engines, each of 110hp. She proved to have a maximum speed of 40mph, which made her the fastest of the Farnborough airships and almost as fast as even the best contemporary aeroplanes.

In November R&M No 59, which had been prepared by O'Gorman, was published. It set on record the extended range of aeroplane type classifications then in use at HM Aeroplane Factory, which were as follows:

B.E. (Blériot Experimental)—Tractor biplanes for general purposes.
F.E. (Farman Experimental)—Pusher biplanes.
R.E. (Reconnaissance Experimental)—Tractor biplanes for reconnaissance.
S.E. (Santos Experimental)—Canard biplane.
T.E. (Tatin Experimental)—Monoplanes with pusher propellers behind the tail.
B.S. (Blériot Scout)—Single-seat tractor scouts.

Following the crash of the S.E.1, no further research was carried out into the canard formula, and the abbreviation S.E. came to stand for Scouting Experimental, replacing B.S. as the designation for single-seat tractor scouts.

Aeroplanes in the R.E. category were intended to be more stable than those in the B.E. class, to which they were otherwise similar, to facilitate observation of the ground beneath them.

The further categories A.E. (Armed Experimental), C.E. (Coastal Experimental), and N.E. (Night-flying Experimental) were added later, as circumstances demanded, but the placement of individual machines within the various classes grew more arbitrary as time went by.

Charles G Grey, now editor of *The Aeroplane* was, throughout his long and distinguished career, constantly critical of the manner in which the government managed British aviation, and was unceasingly critical of the Factory. His editorial for 9 November 1911 included the following comment:

> It is fairly generally known that the erstwhile Army Balloon Factory, now called by the gradiloquent title of the 'Army Aircraft Factory', has been from its very inception an abject failure. The dirigibles turned out by it under the supervision of a highly paid staff of supposedly expert civilian officials, have been either successful toys, or, as in the case of their last effort, useless.
>
> Their aeroplanes have been, as far as one can gather, two in number, one of them was a biplane of the type commonly known as 'tail first'. This, owing to its general design, must obviously have appeared to be a death-trap to anybody with a practical knowledge of aviation, and such it proved to be. The other is a biplane with the engine behind, of a type built by one or two French makers but in reality absolutely out of date. It does not, therefore, require much imagination to see that those responsible for this precious 'factory' must strain every nerve and use every means in their power to justify their existence.

It is clear from this statement that Grey wished all aircraft manufacture to be in private hands, even if it meant a return to empirical research and *ad hoc* development, and that he would go to almost any length to achieve it. It is equally clear that he acknowledged that the S.E.1 and F.E.2 were new designs, not the mere reconstructions of other machines that the War Office

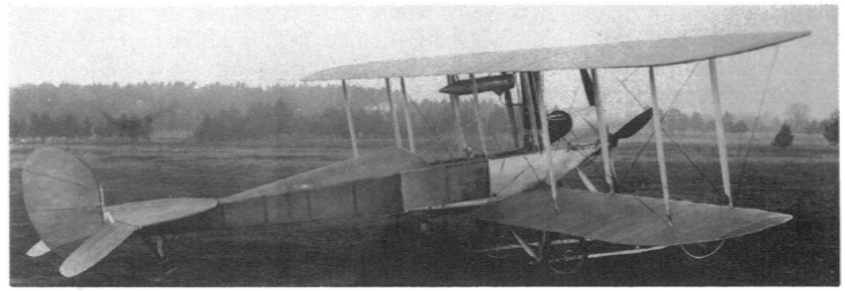
believed them to be.

However, his attitude is perhaps more easily understood when it is remembered that not only has criticism of the actions of Government departments always proved more popular with journalists and their readers than the support thereof, but also that Grey understandably felt obligated to support the cause of the 'trade', which augmented his income by the purchase of advertising space, against its imagined rival, the Farnborough 'Factory', which did not. Furthermore, personal animosity had arisen between Grey and O'Gorman.

On 28 November Joynson-Hicks MP, during a series of parliamentary questions regarding the progress of Britain's air services, enquired how many effective aeroplanes were then owned by the War Department. In a written reply the Under-Secretary of State for War, Col Seely, stated that there were twelve such aeroplanes, with three more under reconstruction at the Factory. These were the Voisin, which would soon re-emerge as a tractor biplane, together with a wrecked Bristol Boxkite and the Paulhan biplane, the novel design of which had not met with great success. These last two machines would eventually be reborn as wholly new aeroplanes.

On 4 December Mr Sandy MP asked, in the House of Commons, what previous experience of aviation and of aeroplane construction any of the officers of the Army Aircraft Factory had before their appointment, and whether the Factory had ever turned out an aeroplane equal in effectiveness to those turned out by private contractors. Col Seely replied, rather obliquely, that the staff of the Factory had been selected on account of their training in the branches of industry which they were to supervise. He stated that the Factory was, at that time, making only one aeroplane for experimental purposes, but that it had also repaired and reconstructed damaged aeroplanes.

Fortunately this repeated sniping did not appear to affect the output or morale of the Factory staff, and their work continued as usual. The new B.E.1 tractor biplane, the design of which had begun earlier in the year, was by now completed. Predictably, nothing remained of the Voisin from which it had allegedly been reconstructed except the 60hp Wolseley engine and its radiator. Instead, the new machine was of prophetically modern layout, and



Geoffrey de Havilland crouches to examine the B.E.1's undercarriage.
(Royal Aerospace Establishment)

had unstaggered two-bay wings, a fully covered fuselage, a large tailplane, and an elegant ear-shaped rudder. There were two seats in tandem, with no decking between them, the pilot being in the rear and the passenger in front, thus placing his weight at the centre of gravity so that the trim was unaltered if the machine was flown solo. This seating arrangement, although it was later to prove disadvantageous for aerial combat, made sound aerodynamic sense, and has found continued favour, particularly in sporting aeroplanes, to this day.

The machine made its first flight on 4 December, with Geoffrey de Havilland at the controls, and was generally satisfactory, although some trouble was experienced with throttle control and de Havilland recommended that the Wolseley carburettor be replaced by a Claudel unit before the next flight. This operation may have proved more difficult than he had supposed, as the B.E.1 did not fly again until after Christmas, when de Havilland made a number of short flights, including several with a passenger.

Unusual in having silencers incorporated into its long exhaust pipes, which themselves served to attenuate the noise of its engine even further, the B.E.1 quickly became known in the press as the 'Silent Army Aeroplane'. The following report from the *Andover Advertiser* of 5 January 1912 is typical of the way in which the public were informed of the machine's existence:

> A new military biplane which enables 'noiseless flight' to be made has been launched from the Army Aircraft Factory at Aldershot, and was engaged in experimental flights on Tuesday, over the district.
>
> It is a biplane with many novel points in its construction, for one thing it works itself by a clever automatic arrangement. The propellers, which are in front, can be started by the pilot unaided, and the engine and propellers are silent when working, there being only a slight hum when close to the ground. A speed of sixty miles an hour has been attained.

It is unfortunate that this report does not make it adequately clear over which district, Aldershot or Andover, the machine had been seen (but not heard), especially as the author has found no record of it flying anywhere on Tuesday 2 January, nor on the previous Tuesday, which was Boxing Day. It is most probable, therefore, that the *Advertiser's* reporter was not recording a first-hand experience, especially when the descriptive errors are also considered. The fact remains that the B.E.1 was remarkably quiet, even if it was not actually silent.

During December 1911 the Factory hosted the second competition for the £1,000 prize for aero-engines offered by Patrick Y Alexander, the first competition having been held elsewhere earlier in the year, without producing an overall winner.

J S Irving, who had joined the Factory staff the previous April as foreman of the engine test shop, appears to have been given charge of conducting the tests, and he had to make several visits to the Midlands to interview and select suitable men to join his staff. The first such appointment was H Moseley, who became Irving's chief assistant and took over when the latter left in 1918.

The engines were tested on two dynamometers which had been installed in the recently completed test house. The electricity generated during the engine tests was absorbed by the electrolysis plant, further reducing the cost of the Factory's hydrogen production.

The competition was, this time, won outright by an in-line eight-cylinder Green engine which developed an average of 66hp throughout the two twelve-hour test runs required by the competition rules. The water-cooled Green was, however, really too heavy to have any serious future, thus still leaving Britain's aircraft industry without an indigenous power unit of any real worth. In recognition of the significance of this problem, particularly in time of war, the Factory was allowed, not without some initial reluctance on the part of its War Office masters, to start work on the design of its own series of aero engines, a move which brought it one step closer to being allowed to design aeroplanes for the Army it was endeavouring to serve.

At the beginning of February 1912 the B.E.1 was joined by a sister machine, identical except for its engine, an air-cooled Renault V-8 of similar power to the earlier machine's Wolseley, but lighter. The new aeroplane was given the designation B.E.2, not to distinguish it as a new type, but merely to give it an individual identity and to acknowledge that it was the second machine built within the general-purpose-tractor class. This machine, too, was passed off as a 'reconstruction', although its parent aeroplane cannot now be positively identified, both a Bristol and a Breguet being suggested by various contemporary sources. The fact that this means of circumventing the restriction on the production of prototype aeroplanes continued to arouse no adverse comment from Whitehall tends to suggest either that those actually responsible for supervising the affairs of the Factory were stupid, or that they were, in reality, fully aware of what was going on, and that no one, except perhaps outsiders, were fooled by these reputed 'reconstructions'.

Testing and development of the B.E.2 took place alongside that of the B.E.1 and other Farnborough machines until 11 March 1912, when the B.E.1 was officially handed over to Capt Burke of the Air Battalion. It was

Geoffrey de Havilland in a B.E.2 outside the RFC hangars which later became famous as the 'Black Sheds'.

given the serial number B1, and three days later the following document*, which is often regarded as the first 'Certificate of Airworthiness', was issued in respect of it:

B.E.1 Certificate

This is to certify that the aeroplane B.E.1 has been thoroughly tested by me, and the mean speed over a 3/4 mile course with a live load of 25 stone and sufficient petrol for 1 hour's flight is 58–59 mph.

The rate of rising loaded as above has been tested up to 600 feet, and found to be at the rate of 155 feet per minute.

The machine has been inverted and suspended from the centre and the wings loaded to three times the normal loading. On examination after this test the aeroplane showed no signs of defect.

(signed) S Heckstall-Smith,
For Superintendent, Army Aircraft Factory.

14th March, 1912.
South Farnborough

Two days later a similar certificate was issued in respect of a Farman, serial number F1, which had been repaired for the Air Battalion by the Factory. This was signed by O'Gorman himself, who may have been wholly unaware that he had been pre-empted by his assistant as he gave this later certificate a prominent number 'one', thereby accidentally guaranteeing confusion for all future historians.

During March a newly designed wireless set was installed in the B.E.2. The results of the numerous tests conducted with it, in which Geoffrey de Havilland flew with a number of different operators, were described as 'good', but no details have been found of what new ground the set may have broken, or what ranges were achieved.

Experimental work was also carried out that spring on the design of float undercarriages, both the B.E.2 and the F.E.2 being so equipped for brief trials. Flights were made from local ponds, but no particular advances were made, and the project was short-lived.

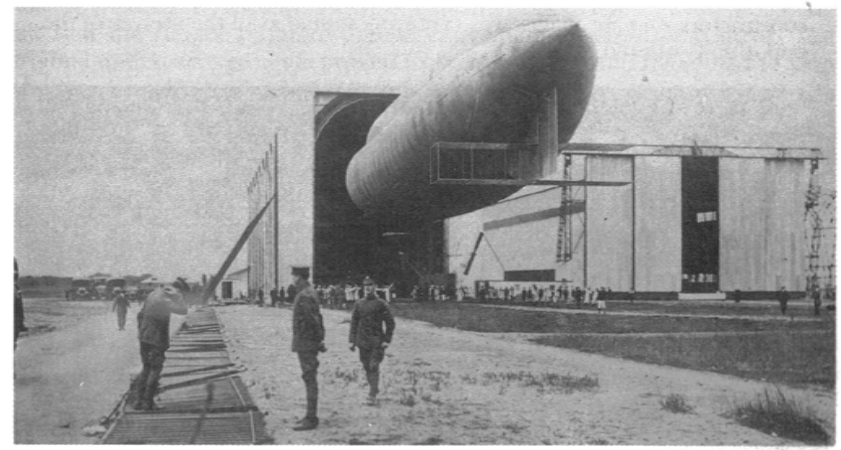
A Government white paper (Cd 6067) entitled *Memorandum on Naval and Military Aviation* was published on 11 April. It formally adopted proposals, made by the Committee of Imperial Defence on 29 February, for the formation of a Royal Flying Corps which was to supersede the Air Battalion, and was to include separate Naval and Military wings together with a joint Central Flying School. The Aircraft Factory was to be granted the prefix 'Royal', was to continue to be administered directly by the War Office, and was to perform the following functions:

1 The higher training of mechanics for the Flying Corps
2 Repairs and reconstructions for the Flying Corps
3 Tests with British and foreign engines and aeroplanes
4 Experimental work

* Public Record Office: AIR1/1608/204/85/32.

5 Manufacture of hydrogen and generally meeting the requirements of the airship and kite squadrons
6 General maintenance as at present.

It was also proposed that additional tree clearance be carried out to improve the Farnborough aerodrome further.

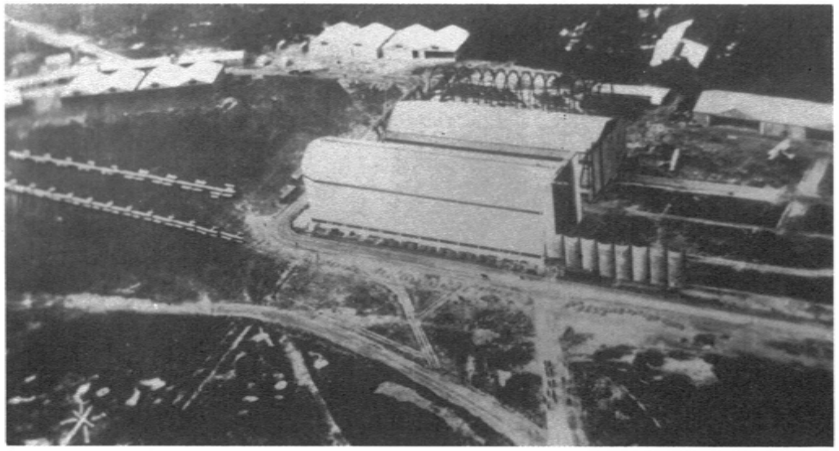


The fence between the Factory compound and Farnborough Common was obviously easily detached to facilitate airship handling, as this photograph shows. The airship is the Astra-Torres, Naval Airship No 3.
(JM Bruce/GS Leslie)

So it was that the Factory finally acquired the name under which it was to achieve its greatest fame, and to suffer its eventual demise, though it still lacked the authority to design prototype aeroplanes. C G Grey obviously anticipated that it would continue to produce them by the same clandestine means as in the recent past. Early in May he renewed his criticism of the Factory's very existence, accusing it of unfair competition with the trade, despite the fact that, only two weeks earlier, he had praised O'Gorman's generosity towards private manufacturers, as shown by the following passage from *The Aeroplane* of 18 April 1912:

> . . . some months ago Mr Mervyn O'Gorman . . . gave an open invitation to all aeroplane constructors to visit the Factory, as he would be pleased to place any information he possessed at their disposal, and it would certainly be a good thing if constructors availed themselves more fully of this invitation. The two new Army biplanes are undoubtedly very fine pieces of work, and contain many points of interest. As may have been gathered from time to time, *The Aeroplane* has not been wholly in agreement with certain of the doings and appointments at the Aircraft Factory, but it is always glad to give credit where credit is due, and undoubtedly there are among the staff of the Factory a number of

exceedingly able men, otherwise, of course, the two biplanes in question could not have been produced; and as Mr O'Gorman is prepared to place the result of the work of these gentlemen at the disposal of British constructors, there is every reason for independent manufacturers to profit by it. A variety of tests of material have also been made, and certain valuable data have been obtained; and as this work is done at the public expense—as, of course, it should be—there is the more reason why British constructors who are themselves taxpayers should avail themselves of the opportunity offered.



Canvas screens were erected to prevent wind gusts affecting the handling of airships entering or leaving the sheds. The aeroplane sheds on Jersey Brow can be seen at the top left.

As the Flying Corps expanded in size and activity, so too did the Royal Aircraft Factory. Ten sheds, intended to house aeroplanes under test, were erected in a sweeping curve across Jersey Brow, to the west of the newer airship hangars, at a cost of approximately £2,500. Additional office accommodation was also constructed to provide working space for the ever-growing technical staff, and cost £2,937. Other expenditure during that financial year included £390 for the erection of airship mooring masts, £2,003 for the purchase of balloon fabric, £2,450 for goldbeater's skins, £2,159 for new engines, £938 for instruments, and £3,214 for wood, wire, dope and sundry other materials for the repair and construction of aeroplanes.

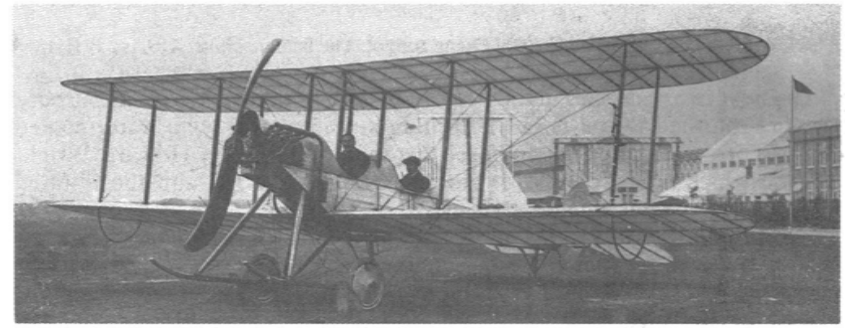
On 3 May the third machine in the general-purpose-tractor class, the B.E.3, made its first flight. For convenience, this aeroplane was alleged to have been reconstructed from the Paulhan, whose presence at Farnborough had been reported, in Parliament, almost six months previously. The new machine followed the same basic layout as its two predecessors but, as might be expected, incorporated several new ideas. Its two-bay wings were staggered, the fuselage was mounted in mid-gap between them, and the

rudder, while being of similar shape to that of the earlier B.E.s, was mounted on top of the rear fuselage on its major axis, so as to be of lower aspect ratio and allow the use of a one-piece elevator. Power was provided by a neatly cowled 50hp Gnome rotary, the fuselage being made wider than those of earlier machines to allow for its diameter.

Immediately following the B.E.3's initial flight de Havilland began to take up passengers, including F M Green and Frank Hearle, even though he felt that the rudder required greater movement to improve control. The original undercarriage skids proved to be too flimsy, and flying had to stop when one broke on landing. A B.E.2-type undercarriage was eventually fitted instead.

In its issue of 16 May *The Aeroplane* went back on the attack, accusing the Factory staff of boorishness in dealing with visitors from the trade, and also suggesting that testing by loading wings with sand was pointless unless carried to destruction, and dangerous because it might strain the structure and so bring about a failure in flight. The article also alleged that no equipment was available by which machines could be inverted for the tests, and that manufacturers whose machines were to be tested were required to supply their own equipment. However, the correspondence page of the following week's edition carried a letter from AV Roe and Co, seeking to correct this erroneous impression and confirming that the Factory did have an overhead crane by means of which a machine could be turned over, together with numerous trestles to support it once inverted. C G Grey, clearly anxious to have the last word, added the postscript that he had heard differently.

Meanwhile, on 15 May HM King George V arrived in Aldershot on an official visit to review troops, and at 4.30pm on 17 May he witnessed what was almost certainly the first official flypast, with de Havilland taking part at the controls of the B.E.2. De Havilland continued to fly this machine throughout the remainder of May and during the early part of June, frequently carrying passengers and conducting numerous trials, including the testing of a new compass designed expressly for use in aeroplanes.



A B.E.2a with an experimental two-bladed propeller. Its wing structure is clearly visible through the translucent clear-doped fabric. The office block, Balloon Shed and new airship sheds are in the background.

Details of a new development of the B.E.2, which incorporated various minor modifications made following its tests, were revealed in R&M 66, which was published on 12 June. The new machine was given the designation B.E.2a. This departure from the previous system by the application of a suffix, rather than the provision of a new number in the B.E. series, was an acknowledgement that the designation 'B.E.2' was now considered to identify a type rather than an individual machine. That the new machine was not to be built by the Royal Aircraft Factory, but ordered in small batches from 'the trade' did little or nothing to appease C G Grey, nor to end his allegations of unfair competition.

On 21 June the B.E.1, which had been returned to the Factory for its Wolseley engine to be replaced by an air-cooled Renault, thereby rendering it virtually identical to the B.E.2, was handed back to the RFC. The removal of the radiator and associated pipework, which was obviously no longer required by the new engine, resulted in marked improvements in performance and forward view.

Three days later de Havilland took the newly completed B.E.4 out for the first time, flying to Laffan's Plain but returning immediately owing to an engine misfire. This machine was, of course, yet another of the Factory's alleged reconstructions, this time from a Bristol Boxkite, which had indeed supplied the 80hp Gnome engine. Apart from its greater power, and the four-bladed propeller to help absorb it, the B.E.4 was, in all respects, similar to the B.E.3.

A line-up of B.E.2as at the Central Flying School. The fifth machine, 416, is a B.E.4.

The next two machines in the Factory's series of two-seat general-purpose tractors returned to the B.E.1/2 formula but employed 60hp water-cooled engines provided by their supposed parent aeroplanes, a Howard Wright biplane which had served with the Air Battalion as F3, and the ill-fated S.E.1, itself a 'reconstructed' Blériot.

It seems that the Howard Wright became the B.E.5 and the S.E.1 the B.E.6, or, more accurately, that such was the cover story given to the War Office, although on one occasion O'Gorman recorded these identities reversed. That such confusion should arise is hardly surprising, as the two new machines were practically identical, their designations being applied before the B.E.2a entered volume production and serving only to give them individual identities. In service use they were given the serials 205 and 206,

and eventually came to be regarded as B.E.2s, which, for all practical purposes, is what they were.

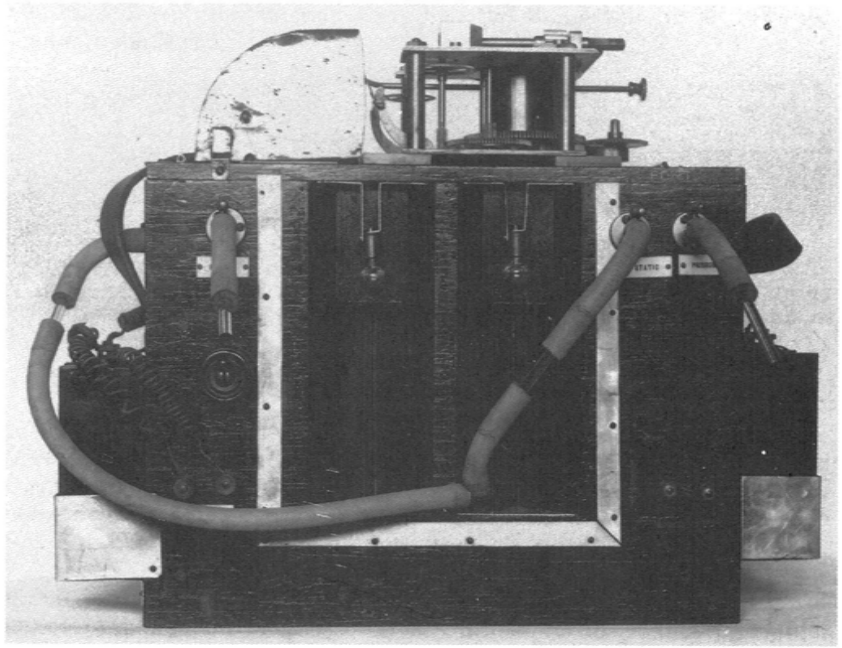
During that summer O'Gorman, still keen to extend the work of the Factory, continued to attract suitable technical and scientific staff by 'head-hunting' promising university graduates, particularly from Cambridge, which was then considered the premier university for mathematics and the sciences. One such recruit was Edward Teshmaker Busk, a brilliant young physicist who joined the Factory staff in June 1912. After taking his degree, Busk had spent an additional year carrying out post-graduate research on self-regulating carburettors. Following a period in industry, he had been conducting private research into stresses in tension wires and into the causes and effects of wind gusts.

Acting upon a recommendation made by Professor Hopkinson, a Cambridge Fellow, and endorsed by Dr Glazebrook of the NPL, O'Gorman offered Busk a position as Assistant Engineer/Physicist. He accepted gladly, and was eventually to create the Factory's first truly inherently-stable aeroplane, working on entirely different principles to those advocated by Dunne some six years previously. As an aid to his investigations the ever-smiling Busk quickly learnt to fly, but steadfastly refused to wear a helmet, preferring to feel the wind in his hair.

Military and other trials

In December 1911 it had been announced that a competition would be held at Larkhill, on Salisbury Plain, in August 1912 to determine with which aeroplanes the British Army was to be equipped. The intention was that its flying services should adopt a standard aeroplane, just as it had previously chosen a standard rifle, field gun, wagon etc, which could be purchased in quantity and used, without modification, for a reasonable period. Thus, in a memo to the Director of Fortification and Works at the War Office, Maj Bannerman, Commandant of the Air Battalion, stated: '. . . it would seem inadvisable to purchase more machines of differing types. Our first aim now is to get two patterns which can be regarded as standard for the next twelve months.'

In addition to the prospect of volume sales, generous cash prizes were offered, thereby encouraging the widest possible field of entries. That the competition was not to be restricted to machines of wholly British manufacture was of obvious annoyance to C G Grey, and his editorial column in *The Aeroplane* concerned itself with little else for some time.



The Factory's Trajectograph, which was designed for use in the Military Trials to measure gliding angle.
(Royal Aerospace Establishment)

To obtain the most accurate results possible for a number of the tests required by the rules of the competition, which became popularly known as the 'Military Trials', the Royal Aircraft Factory staff designed several completely new instruments. One of these, the Trajectograph, measured the angle of descent of a gliding aeroplane, and was the first device ever to do so. This ingenious device combined a pitot/static tube measuring forward velocity with a barograph measuring atmospheric pressure (and thus altitude), each instrument recording its readings on a chart upon which time intervals were marked, as dots, by a pencil operated by a clockwork motor. The Trajectograph, which was mounted within a wooden box to be carried by the aeroplane under test, appears to have been the brainchild of a Mr F Short, who also took charge of its operation throughout the competition, being assisted in his work by Busk.

Thirty-two aeroplanes were assigned competition entry numbers, but eight never even arrived at Larkhill, and of those which did, several never actually took part in the flying.

Since Mervyn O'Gorman, as Superintendent of the Royal Aircraft Factory, was *ex officio* a member of the panel appointed to judge the competition (the others were Brig-Gen Henderson, Maj Sykes and Capt Paine RN), it was obviously inappropriate for any aeroplane designed or produced at Farnborough to compete in the trials. Nevertheless, during the period of the trials the B.E.2 was flown down to Salisbury Plain by Geoffrey de Havilland to provide a readily available and proven 'hack' for O'Gorman. In addition, advantage was taken of the test facilities available there, thus adding to the Factory's knowledge of its own products and providing a direct comparison with the best machines that private enterprise could produce.

Naturally this *hors concours* participation in the flying tests was viewed with disfavour by some sections of the aviation press. However, the reporter from *Flight*, who was granted a brief flight in the B.E.2, was much more complimentary, as the following passage, published in the issue of 17 August 1912, demonstrates:

> And there stands B.E.2 quietly on the grass in the next field, inviting a ride. 'Will you take me back to the sheds . . . ?' I ask, and, 'Yes, certainly, but you may find it bumpy,' says G de H, putting on his flying cap and goggles, while I clamber into the front seat, a wicker basket affair that seems uncommonly comfortable. Going to the propeller de Havilland gives it a pull round, as one would start a motor-car engine, and the 70hp Renault gets gently into action. No one holds the machine as the pilot calmly walks round to the back and gets into his seat, for the engine is throttled down to a speed at which the propeller draught exerts but an insignificant thrust compared with that which is presently to come.
>
> Opening the throttle a little we turn round into position, for at first the machine was within a few feet of the fence, and accelerate down wind. Not a bump of any description comes to indicate whether or no we are still in contact with the earth, but it is quite certain a moment later that we are flying as with a quiet but determined stride the machine steps up into the air. And then the ascent continues and the ground that used to be in front

of one's eyes lays itself down like a carpet to be looked upon and walked over with fairy-like footsteps from above . . .

As for the going of the machine, we were running with the wind at anything between 75 and 80 miles an hour and it seemed as steady as a rock. Once there was a little drop such as a small boat might give in a 'lop' and once a little heave as we passed through a choppy sea. And now the sheds are just in front, so de Havilland puts round into the wind on a small bank and we glide downwards with a smooth easy motion that appeals to me as the most exhilarating part of a flight and one least associated in my mind with any feeling of nervousness, notwithstanding that the ground approaches with an amazing rapidity. At the last moment, a skilful movement of the elevator flattens the machine so that it flies parallel to the ground and a second later the wheels touch the grass and we come to rest on terra firma once more.

Of all the events in the trials, none have impressed me more than this simple flying to and fro. Neither the intricate manoeuvring of the Deperdussin by Prevost, the 'flat gliding' by Verrier on the Maurice Farman, the rocket-like ascent of Bielovucic on the Hanriot, the wind riding by Bell on the Martin Handasyde, nor the several performances of other excellent machines have quite served to bring home the utility of the aeroplane as did the simple assurance with which de Havilland used B.E.2 in the service of those who had occasion to go from place to place.

One of the neatest biplanes ever built, and one moreover that impresses the engineering sense with an immediate satisfaction in the quality of its design, B.E.2 demonstrates the value of scientifically practical research at its every flight. It is never flown save with a purpose, and few flights fail to bring some factor of utility to the store of knowledge possessed by the RAF.

The writer continued with a lengthy and detailed description of the machine, praising its design and construction, then added the following observation:

> It is difficult to explain in words the precise quality in the design of this machine that calls forth the admiration of the engineer, and it is certainly not in any way due to smart finish of superficial details, for although the workmanship is excellent, the hand of the experimenter is on it still. The fact remains, that for a well-designed tractor biplane, B.E.2 of the RAF is hard to beat, and some points in it might well be worth copying by those in search of Army orders.

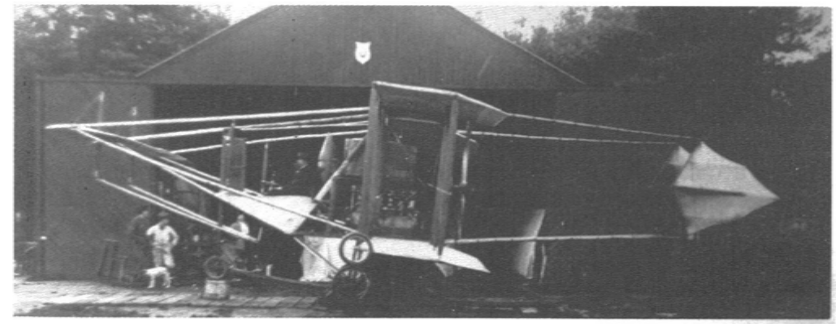
The trials afforded the B.E.2 a further opportunity to impress the Factory's critics when, on 12 August, de Havilland took off shortly after dawn, accompanied by Maj Sykes, taking advantage of the cool calm air of the early morning to test the machine's climbing ability. One thousand feet was reached in just under three minutes, and half an hour later they had reached 7,000ft and were still climbing well. De Havilland kept the machine in a climbing attitude until he was sure they could get no higher. He then returned to earth, his petrol almost exhausted, eventually landing at about 8.00am. The barograph on board confirmed that they had reached an

altitude of 10,560ft, and had secured the British altitude record not only for passenger flights, but for solo flights as well.

While O'Gorman was understandably pleased by this demonstration of the abilities of his staff, his mind was clearly concentrated on more mundane matters, for that same day he made a request to the Master General of Ordnance that his title be changed from Superintendent to Director. His reasoning was not stated, but it was most probably because the latter implied a greater degree of actual control than did the former. Whatever the reasoning, the change was eventually made, but not until the Second World War.

The Military Trials continued throughout August, with interim results being published, together with a great deal of editorial comment, in all of the popular aviation magazines.

Finally it was announced that, according to the judging formula used, which gave consideration not only to aeronautical ability, but also to forward view, ease of dismantling and reassembly, ability to land on rough ground, and a host of other attributes thought to be of special importance for military purposes, the winner in both the British and Open Classes was S F Cody's 'Cathedral'. This huge and anachronistic machine, which was a direct descendant of British Army Aeroplane No 1, first flown at Farnborough almost four years previously, was therefore purchased, together with another example, for use by the RFC, as had been guaranteed by the entry conditions.



S F Cody's victorious Military Trials machine outside his shed on Laffan's Plain. The greater modernity of contemporary Farnborough designs such as the B.E.2 is all too obvious.

Whatever the competition rules had stipulated, the Cody machines were far from ideal for their intended purpose, so the War Office chose instead to adopt the B.E.2, which had produced unofficial results at least equal to those of Cody's machine in the rôle for which it had been conceived, as a general-purpose military aeroplane. The initial order, for four machines to the revised B.E.2a standard, was placed with the British and Colonial Aircraft Company (Bristol), which also received an order from the Government of Australia for two similar machines for use by its own air

service. Orders for five machines each were also placed with Handley Page and Vickers.

Although the placing of these orders was a clear indication of the veracity of the frequently expressed assurance that the Royal Aircraft Factory was not a manufacturing establishment, and therefore presented no threat to the trade, C G Grey remained unconvinced. So did the pioneer Alliot Verdon Roe, whose autobiography*, published many years later, contains the following passage:

> The conclusion of the [Military] Trials did not mean that the British aircraft industry became satisfied with Government action and policy. There was incessant criticism of the lack of support which was given to us and one of our chief causes of annoyance was the policy adopted by the Royal Aircraft Factory where it was officially stated only experimental machines were being built. We were able to place little faith in this assurance for the industry was only able to secure small orders, and these were invariably only procured after endless agitation both in Parliament and in the Press.

Roe should have been the first to acknowledge that production orders were scarce, for immediately upon learning of Cody's success in the Military Trials he wrote to him, offering to build the aeroplanes which he felt would now be ordered, thus leaving Cody free to concentrate on design.

He also stated (ibid):

> Even when our machines were purchased by the Army we found that when they were in need of repairs and renewal they used to be sent to this Factory which most of us regarded as being our most dangerous competitor.

Once a machine had been purchased, surely its owners could send it anywhere they chose for maintenance and repair? Since the War Office had

The Royal Aircraft Factory viewed from near to the main road, probably late in 1912. Farnborough Common is to the left.
(via Paul S Leaman)

* *The World of Wings and Things,* (Hurst and Blackett, London, 1939).

decreed that care of the RFC's aircraft was one of the Royal Aircraft Factory's principal roles, it was entirely logical that damaged machines should be sent there, as they had been before AV Roe ever went into business.

Other research work which had been carried out under the direction of O'Gorman, both at the Royal Aircraft Factory and at the National Physical Laboratory, was described, in copious detail, in the *Technical Report of the Advisory Committee for Aeronautics*, published in early November 1912.

Tests with scale models of dirigibles, suspended variously in streams of air and water, had enabled the accurate calculation of the resistance of differing designs of airship envelope, utilising the principle known as 'dynamical similarity' which had been discovered at the NPL and described in the 1910 report of the Advisory Committee.

Research into the properties of aerofoil sections had prompted the suggestion that the upper and lower surfaces ought to be considered and designed separately, the top section being the more important for normal flight angles, with the negative pressure (which provides most of the lift) being at its maximum at angles of incidence between five and ten degrees. These results generally confirmed the conclusions reached, empirically, by previous investigations, and assisted greatly in the design of new and improved aerofoil sections.

It had also been established that the commonly followed principle that the gap between multiplane wings should be equal to the chord was not as successful as had been supposed in reducing the loss of lift caused by interference between them, the actual loss being about 17 per cent. If the gap was increased to 1.6 times the chord, the loss of lift was reduced to around 10 per cent, although it was acknowledged that structural considerations would usually preclude the use of such a large gap. Staggering the wings by a distance equal to 40 per cent of the gap, as in the B.E.3 and B.E.4, was found to reduce the loss of lift further, and also, incidentally, to improve the pilot's view of the ground ahead.

It is far from remarkable that graduate engineers such as O'Gorman and Busk should seek to carry out research of this nature, but it is somewhat surprising that a Government body should publish its results so freely, rather than considering them to be secret. Thus the Factory continued to co-operate with the industry, even if its motives were frequently viewed with some suspicion, and many manufacturers happily took advantage of the information made available to them free of charge.

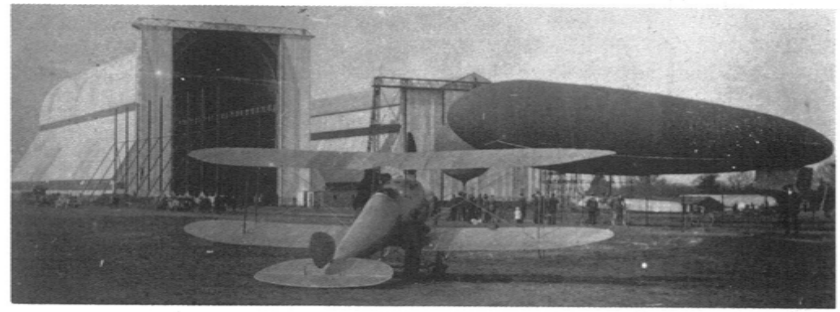
During February 1913 a B.E.2 and the airship *Delta* were exhibited at the Aero Show, which was held at Olympia in London, together with the massive Cody biplane which had won the Larkhill Military Trials. While the War Office's reasons for placing these machines in a public exhibition cannot be ascertained exactly, it seems most probable that the intention was to impress the British taxpayer, rather than to frighten potential foes with a display of aerial might (even though the Dreadnought race was still running). Certainly the War Office could neither have anticipated a flood of orders from Foreign powers, nor have welcomed such orders from members of the public.

HM Aircraft Factory early in 1912. The extension to the original building can be clearly seen. The three buildings at the top of the photograph are the later airship sheds, that on the right being the portable shed, with its canvas covering in place.
(British Balloon Museum and Library)

In its issue of 15 March *Flight* contained a leader in response to a letter from the Amalgamated Society of Engineers, which was protesting against criticisms levelled by another magazine at 'the conduct of the workmen employed at the Royal Aircraft Factory'. *Flight* expressed the opinion that: '. . . the Royal Aircraft Factory is a first-class national asset, and that it has accomplished uncommonly good work for the money that has been spent upon it'.

On the same date O'Gorman, in a handwritten letter addressed to the Director of Fortification and Works (DFW), his superior at the War Office, explained that he had succeeded in completing an aeroplane additional to the number previously anticipated. Since no reference was made to any 'reconstruction' or other excuse to explain the existence of this machine, it seems clear that the DFW now knew that the Factory was actively designing

prototype aeroplanes. Since it as yet had no official authority to do so, it appears that the DFW was prepared to turn a blind eye to these activities.

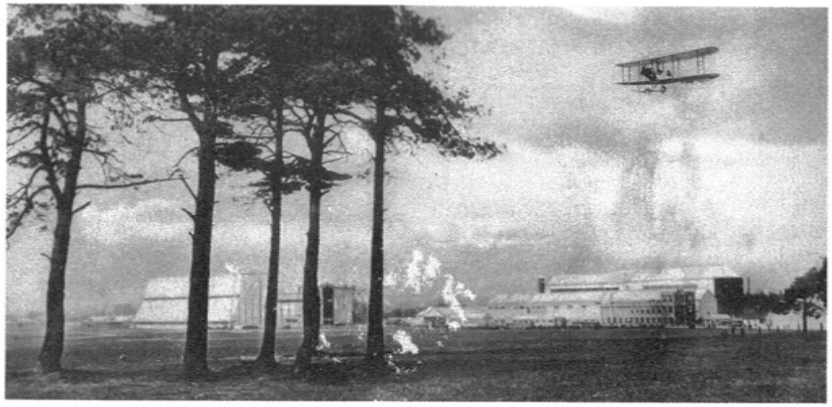


The very advanced B.S.1 ouside the Factory compound, with the new airship sheds, a spherical balloon, and the airship *Gamma II* in the background.

The aeroplane in question, which O'Gorman describes in his letter as 'a tractor biplane with a perfectly smooth round fuselage', represented a quantum leap forward in aircraft design. It was the B.S.1, the world's first single-seat scout, the design and construction of which had started during the previous year. It therefore considerably antedated the Sopwith Tabloid, for which this title is frequently claimed. The B.S.1 was a single-bay, staggered biplane, with bracing wires swaged to a streamlined oval section, exactly as suggested by O'Gorman in the design brief for the B.E.1, prepared almost two years before. The fuselage was a wooden semi-monocoque structure made from strips of mahogany three-ply, and the tail surfaces were quite obviously derived from those of the B.E.3. Lateral control was by wing warping. Power was provided by a fourteen-cylinder two-row Gnome, rated by its manufacturers at 120hp but actually producing rather less, which was housed within a well streamlined cowling. While the neat overall appearance was slightly spoiled by the seemingly heavy twin-skid undercarriage, which current practice and the Farnborough Common terrain made obligatory, it was an attractive aeroplane, and achieved the very commendable speed of 92mph with its designer, Geoffrey de Havilland, at the controls.

Following initial tests of the B.S.1, de Havilland decided that, as a result of scaling down, the rudder was too small to offset the side area of the forward fuselage. He designed a larger replacement, but continued to fly the machine while waiting for it to be made. However, on 27 March he entered a spin while turning and crashed, fracturing his jaw and losing several teeth.

O'Gorman's diary entry for the following day includes details of de Havilland's hospital and his private address, presumably so that O'Gorman could express his sympathy to his test pilot's wife. O'Gorman also endeavoured to obtain compensation for de Havilland's injuries, but there is no record that any was paid.



This view across Farnborough Common towards the Factory site was taken during 1913–14. The B.E.2 flying overhead was added in the photographer's studio.

The aeroplane was quite extensively damaged, but was quickly rebuilt with totally redesigned tail surfaces which included a large rudder, together with dorsal and ventral fins. The installation of a new engine, a nine-cylinder Gnome rotary more realistically rated at 80hp, reduced its speed to a still very creditable 85mph. By this time the class designation 'Blériot Scout' had been dropped in favour of 'Scouting Experimental', so the machine became known as the S.E.2. It was the first in a family of high-speed scouts which were among the best aeroplanes of their time.

Work on the development of aero engines was proceeding with the design and evaluation of single-cylinder test units, and a metallurgy department was established, under the supervision of a Mr Pilgrim, to ascertain the best metals and the treatment thereof for each individual component. This department was also heavily involved in the development of streamlined bracing wires, finally establishing the process of heat treatment in a bath of molten tin.

On 22 March *Flight* published a letter from O'Gorman in which he offered the use of the Factory's facilities to test any engine intended for aeronautical purposes. No charge was to be made for carrying out such tests, which were regarded as being in the public interest, nor for the petrol and oil consumed. The only stipulation was that a skilled mechanic should be present to represent the manufacturer or agent putting forward the engine to be tested.

Also published in March 1913 were details of tests conducted upon a 1/16th scale model of a B.E.2a to determine lift and 'drift' (as drag was frequently called at that time). The model, made of brass, was suspended in a windtunnel at an airspeed of thirty feet per second and tested at angles of incidence between −45° to +45°. During these tests it was discovered that the elevator was only effective at angles between plus or minus 30°. Beyond those points it had no further effect, and any provision for greater travel was therefore unnecessary.

A memorandum (AC-10) from the Air Committee, dated 20 February 1913, had recommended that the Superintendent of the Royal Aircraft Factory should be made responsible for maintaining a list of all privately owned aircraft in the United Kingdom, and that it should be updated twice a year, on 1 April and 1 October. This recommendation was adopted, and O'Gorman's first list, published on 29 April 1913, contained details of ninety-nine machines, including their current location, engine, control system, etcetera.

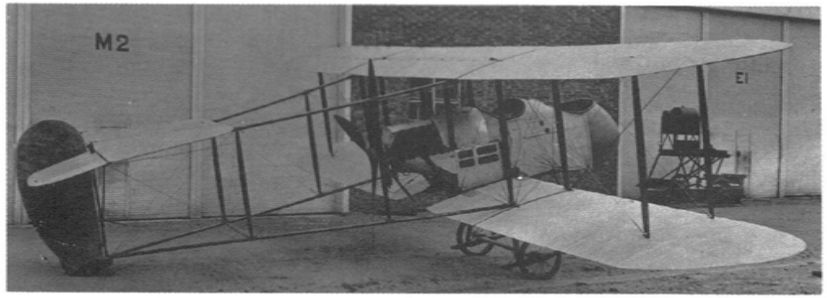
On 4 May E T Busk attended a soirée of the Royal Society in order to demonstrate the Factory's newly developed test instrument, the Ripograph. This was a development of the Trajectograph which had been used with great success at the Military Trials, and recorded, on a single photographic strip, the pilot's movements in warping and steering, together with speed, inclination, roll angle and elapsed time. This instrument was to prove of considerable assistance to Busk in his researches into aircraft control and stability.

An assortment of Royal Aircraft Factory designs in front of the RFC sheds on Farnborough Common. Aircraft 206 was built as B.E.6, 239 and 329 are B.E.2as, and behind them is the R.E.1.

One product of that research was the Factory's first inherently stable aeroplane, the R.E.1. Reported as being complete late in May 1913, although it was not handed over for test flying until July, it generally followed the B.E. formula but embodied features resulting from Busk's experiments with windtunnel models and full-scale aeroplanes. A biplane, it had single-bay wings with wing warping for lateral control. A notable feature of its construction was the use of welded steel tube in its fuselage framework, eliminating some of the trueing-up of wire bracing attendant upon a wooden structure.

On 5 June the King and Queen visited Laffan's Plain to review the RFC. The airships *Gamma* and *Delta* were inspected in their sheds, as were a variety of aeroplanes, including several B.Es. His Majesty later congratulated the RFC on its marked progress and *esprit de corps*, and, in the Honours List traditionally published to celebrate the Monarch's official birthday, O'Gorman was appointed Companion of the Most Honourable Order of the Bath, in recognition of his contribution to aeronautics.

By the summer the F.E.2 had been totally rebuilt, emerging from the Factory's workshops as an entirely new aeroplane. The continued use of the designation F.E.2, without a suffix to distinguish it from the earlier machine as was now the Factory's standard practice, tends to suggest that the



The 1913 version of the F.E.2 outside the Factory workshop.
(JM Bruce/GS Leslie)

'reconstruction' ploy was used to account for the existence of the new machine, although no documentary evidence has been found to support this hypothesis.

Still a nacelle-type pusher, the new F.E.2 was powered by a 70hp Renault V-8 and had a broad centre-section to which were attached standard B.E.2a wing panels, giving it a total span of forty-two feet. Lateral control was still by warping. At the end of March the War Office had asked O'Gorman to provide mountings for a variety of machine guns, in order to continue trials into the possibilities of aerial combat. The new F.E.2 was selected as the most suitable vehicle for the tests, and, like its earlier namesake, it was fitted, briefly, with a Maxim gun, and then with a Vickers quick-firing gun, mounted on the rim of the forward cockpit to place it within easy reach of the observer and to give a generous forward field of fire.

The Royal Aircraft Factory viewed from Farnborough Common, with the office block in the centre, the original Balloon Shed and Airship Shed behind it, and the new airship sheds to the left of the picture. The portable shed is uncovered.
(British Balloon Museum and Library)

On 11 June the Factory site was enlarged by the purchase of a piece of land adjoining its northern boundary, allowing its continued development without encroachment on the area of Farnborough Common used for flying. The new office block, within the original site, was completed at about this time, and a large whirling arm to augment the windtunnel, particularly for propeller testing, was built in what had previously been a separate compound at the eastern end of the site, bringing the Factory closer to the Swan Inn and the Farnborough Road.

Another improvement carried out in the summer of 1913 was the deepening of Fleet Pond, which was then used for flotation tests of the Factory's new hydro-aeroplane, the H.R.E.2, the construction of which was completed early in July.

The F.E.3, which was also completed that summer, was an attempt to improve the performance of the F.E. class of machine by eliminating the drag of numerous booms and wires normally associated with the pusher design. The concept of aeroplane armament at that time assumed that the gun should be operated by an observer/gunner, not by the pilot, who was thought to have quite enough to do manoeuvring the machine into position, and that it should be mounted so as to cover as wide a field of fire as possible. The lack of any synchronisation system to allow a gun to fire forward through the arc of a tractor propeller made the pusher layout essential. Its only disadvantage was its performance, which hitherto had always been inferior to that of a tractor aeroplane of similar size and power. Therefore, in a bold attempt to reduce the drag and enhance the rearward field of fire, the tailbooms which created so much of the additional resistance were eliminated in the F.E.3 by having the tail unit carried by a tubular sleeve which was supported from the propeller shaft by bearings and braced by wires to the wings and undercarriage.

Testing was cut short when a propeller blade broke in flight, necessitating

The innovative F.E.3, showing its single tailboom and the nose aperture which admitted air to the internally mounted radiator.
(Royal Aerospace Establishment)

a hurried forced landing. Fortunately the machine was at no great altitude, and a landing was achieved without undue damage. However, it had already become obvious that the tail lacked sufficient strength for the tests to be completed in safety, and the trials were discontinued, the knowledge obtained from them being of immediate benefit in the development of its successor, the design of which was started immediately.

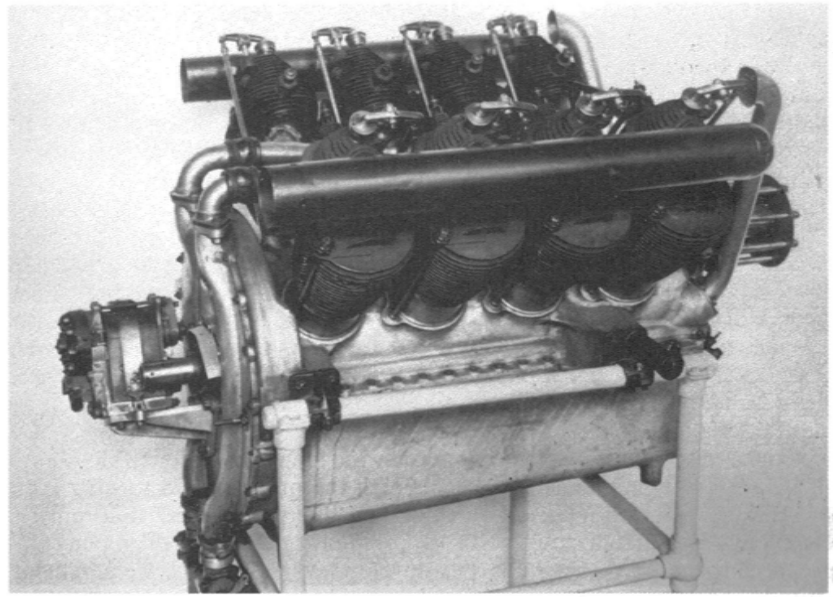
Flight magazine for 2 August described how the Factory now carried out static load testing of the wings of inverted aeroplanes by using long narrow bags of lead shot. This improvement on the previous method of simply piling on loose sand was made both in the interest of easier handling and in response to criticism that the sand might enter the structure and accelerate wear on moving parts, although exactly how this could happen was not explained by the original critic.

The Factory's newest airship, predictably named *Eta*, made its first flight on 19 August. It was a non-rigid of 118,000 cu ft capacity, and broke new ground in that the car, instead of being suspended from bands or netting over the envelope, as in previous craft, was hung from steel rings attached, via a cotton patch, to the actual fabric of the envelope. These 'Eta Patches', as they became known, were used on a great number of later airships, including the Submarine Scouts which gave sterling service with the Royal Naval Air Service on anti-submarine patrol and convoy escort duties during the Great War.

Eta's envelope, like that of its immediate predecessor, was of treated fabric, for goldbeater's skin had finally been at least equalled, and very possibly bettered, by the invention, by J E Ramsbottom, of Delta Dope, a protective varnish which had already been used to render the leaky envelope of *Delta* more nearly impervious to hydrogen. Thus it was now possible to fabricate airship envelopes from cotton or linen fabric, which was far easier to work and to make attachments to than goldbeater's skin, and then render them gas-tight once they were completed.

What is frequently claimed to have been the first truly efficient aeroplane compass was produced by the Factory's instrument department towards the end of 1913. That this vital navigational aid had only been created after numerous failures and constant development is clearly illustrated by the fact that the successful variant, adopted for general use, was designated the R.A.F. Mk IV.

The engine department had also been busy, and its first indigenous aeroplane engine, an air-cooled V-8 loosely based on the Renault which was already in widespread use, was undergoing testing and development. The Farnborough version, designated, with commendable simplicity, R.A.F.1, gave an output of 90hp from a swept volume of approximately nine litres at 1,800rpm. This rotational speed, which was unusually high for the period, was possible because the propeller was not mounted directly on to the crankshaft, but on to an extension of the camshaft, which was positioned within the vee of the cylinders and operated the side inlet valves directly and the overhead exhaust via pushrods. This ingenious idea, which was copied from the Renault, provided a simple and effective reduction gear, albeit at the expense of having to increase the strength, and consequently the weight,



The R.A.F.1a 90hp V-8 engine. Note the crankcase breather pipes, which were designed to blow an oil mist on to the exposed valve gear.

of the camshaft, thereby slightly reducing the already unremarkable efficiency of the engine.

The cylinders were slightly offset, those on the starboard side being slightly forward of their counterparts to port in order to allow each connecting-rod big-end a separate crankshaft journal, eliminating any need for the complex devices often employed in vee engines. In the interest of greater reliability, the cylinder heads were made integral with the cylinder, eliminating joints and gaskets and a potential loss of compression and consequent further reduction in efficiency. Since each cylinder could fairly easily be removed from the crankcase for maintenance, which was frequently needed by engines of the period, this seemingly retrograde step did not, in reality, make the care of the R.A.F.1 any more difficult than that of its rivals.

Following contemporary practice it had cast-iron pistons, each fitted with three rings, the cylinders also being of cast iron. Despite the provision of a cowl or scoop which directed some of the propeller slipstream on to the cylinders, baffles being provided to guide it across as great an area as possible, cooling remained marginal, and the engine normally operated on an over-rich mixture to guard against any further overheating. Lubrication was assisted by a light steel flywheel within the crankcase, which dipped into the sump and splashed oil into channels which conveyed it to the main bearings, from where it was forced, centrifugally, through oilways to the

big-end bearings. A breather pipe at the front of each cylinder bank allowed an oil mist to drift up from the crankcase to lubricate the exposed valve gear, any surplus being burnt off.

Following exhaustive bench testing and evaluation, a developed version, the R.A.F.1a, was designed with a view to volume production.

Construction of the Factory's second venture into engine design was completed during October and, naturally enough, this was designated R.A.F.2. It was a nine-cylinder radial with a swept volume slightly in excess of ten litres, and was designed to deliver 120hp. Tests appear to have been discontinued at a fairly early stage, most probably because the engine would never have been able to compete on equal terms with the numerous rotary engines of similar power which were being developed by private makers.

Wide as the Factory's interests and fields of expertise had become, O'Gorman recognised that there would always remain areas in which others might be more expert. Therefore, when a series of mishaps experienced by the RFC made it apparent that existing wheels were not sufficiently robust to withstand the stresses of heavy or crosswind landings, he sent a circular to all known wheel manufacturers, explaining the problem and inviting their suggestions for improvements. It was eventually realised that only a completely new design would solve the problem, and only one company was prepared to undertake the necessary development work, an understandable attitude considering the very small volume of business created by aeroplane wheels at the time. As a result not only was a new and satisfactory wheel developed, but for the next few years a virtual monopoly was enjoyed by the Palmer Cord Tyre Company, whose engineers produced the design.

On 1 October O'Gorman completed an updated list of all civilian aeroplanes in England. Eighty-three machines were listed, the reduction from the April total being due to the omission of all machines either of a truly experimental nature or powered by engines of less than 50hp, since it was felt that neither category would be of use to the flying services in times of war. This consideration, applied retrospectively, reduced the April total from ninety-nine to fifty-five.

On 18 October *Flight* published a three-page article describing the Royal Aircraft Factory's calculation of the stresses within the structure of an aeroplane wing, the example used being the B.E.2. The author suggested that others (i.e. private industry) might make use of the method and emulate the Factory's example of establishing the dimensions of structural members by calculation, rather than by intuition.

Finally, with a total absence of any fuss or ceremony, on 14 November 1913 the War Office acknowledged that the Factory was building new aeroplanes to its own designs, and gave it an official mandate to do so. That this apparent change of heart appears to have aroused no immediate comment either in the newspapers or in the aviation press demonstrates that it was not regarded, except perhaps in Government circles, as in any way new, or different to what had gone on before. However, the true import of the reversal was realised a little later, when production of a batch of twenty-four R.E.5s was started by the Factory workshops. The Factory's enemies howled in protest, declaring that the order ought to have been

An aerial view of the factory in late 1913 or early 1914. The two long sheds in the left foreground are the RFC hangars which later became famous as the 'Black Sheds,' and in front of them is 'Cody's Tree'. The workshop blocks are at centre right. The two gasholders were built in 1908 to replace those previously used, and were themselves demolished in 1918.
(British Balloon Museum and Library)

given to the trade. Yet, only a few weeks later, it was stated by the same writer that those companies now building B.E.2s to War Office contracts would prefer to be building machines of their own design. While this was an understandable sentiment, no explanation was offered as to why the industry apparently wished for orders to build one Factory design, yet resented orders to build another.

Finally, *The Aeroplane* declared:

> The Trade has little to fear from the Royal Aircraft Factory as a competitor, for Government dockyards seldom disturb the equanimity of the big ship building firms, in fact, an aeronautical dockyard is practically a necessity, and is certainly desirable.
>
> As an experimental workshop also the RAF can be very useful for it will keep the 'Trade' on the move.

Thus C G Grey brought this particular argument to a close, final victory eluding either side.

Tested in battle

The first day of 1914 marked the end of an era, when, on instructions from Whitehall, all of the War Office's airships were handed over to the admiralty for operation by the Royal Naval Air Service (as the Naval Wing of the RFC had become). It had been decided that, in time of war, the defence of Britain's shores would rest in the hands of the Navy, and it was felt that the airship, with its superior endurance compared with that of the aeroplane, would be of particular value for anti-submarine patrol. It had been agreed that the Navy would pay £25,000 to the RFC for the airships, the money being allocated to cover the cost of the batch of twenty-four R.E.5s already under construction at the Royal Aircraft Factory.

Thus the Factory's involvement with airships came to an end, its final design, *Epsilon*, remaining unfinished.

The very next day details were announced of the formation of a separate inspection department of the Royal Flying Corps, based at Farnborough, Treasury sanction for which had been given the previous October. The Chief Inspector who would head the new department was to be Maj J D B Fulton. Its initial complement of staff was to be twenty-four, most of whom were to be transferred from the Royal Aircraft Factory, which had previously carried out this work. Geoffrey de Havilland was appointed Inspector of Aeroplanes, at an annual salary of £550, and was replaced as chief test pilot at the Factory by Ronald Kemp. De Havilland, however, found this move to be far from agreeable, preferring to design aeroplanes rather than to inspect the work of others. Within a few months he had left to join Holt Thomas's Aircraft Manufacturing Company at Hendon, which had hitherto produced French designs under licence. Here he began to design a series of aeroplanes bearing his own initials, the first of which bore some resemblance to his previous design, the F.E.2.

The Aeronautical Inspection Department, or AID as it quickly became known, was to inspect all repairs and all new airframes and engines intended for use by the RFC at the manufacturers' premises, and conduct the final acceptance tests of finished aeroplanes. Predictably, G C Grey seized upon the opportunity to continue his war against the Royal Aircraft Factory, and welcomed the AID because he felt it would reduce the Factory's power to 'queer the pitch' of the industry, although such power existed only in his own mind.

However, the Farnborough designs had by now found support with RFC pilots, who not only found them pleasant to fly, but felt reassured as to their quality and safety by the programme of development and testing carried out at the Factory.

The Times, in an article on aeronautics published on Thursday 8 January 1914, was equally supportive, and observed that the Government had taken the following steps to ensure an adequate supply of aeroplanes to the Services:

a To buy specimens of every really promising British and foreign machine and try them.

b To organise, in the Advisory Committee for Aeronautics, a scientific centre of advice on the pure science of flight.

c To organise, at the Royal Aircraft Factory, an engineering centre where ideas (to determine the type of aircraft needed by the services) could be tried, repairs effected, and standardisation studied.

d To invite the machines of the whole world to a military aeroplane competition in order that comparison might be made.

e To buy the best machines thus indicated . . . Although not in the competition, the Government's own B.E. machine is known to have surpassed all the rest in almost every particular.

f To give orders to all British makers who could or would make to a selected design, in such numbers as would fill their capacity for output, so as to give them an opportunity of putting their works upon an industrial, instead of merely experimental basis.

g To construct a certain percentage of machines in its own factory, with the object of being able to control prices and of keeping together a competent staff, with whom safety and other excellence of results should outweigh considerations of shareholders profit.

The newspaper went on to comment that almost every one of these steps had met with criticism, and that the ordering of British machines gave rise to bitterness among the 'Trade'. It then continued:

> But the chief *'bête noire'* of the 'trade'—or, rather, of the more vocal section of it—is the Royal Aircraft Factory. This institution is vehemently accused of using the public funds in order to compete with the private constructor. It has, indeed, by producing the excellent designs known as B.E.2 and B.E.8, helped the Government out of a difficult situation. But the giving out in the past year to six or seven firms of orders for some 80 machines of these types, whereby the Government hoped at the same time to organise the 'trade' and to supply itself rapidly with machines, does not appear to have given satisfaction from either point of view. On the other hand, owing to the immaturity of the business, none of the firms have hitherto succeeded in delivering their machines on the dates fixed, without let or hindrance, by themselves. The amount of delay has ranged between 410 days and 57. The average time overdue is four months.
>
> The orders given, however, have had a most marked effect on the organisation of the firms executing them. Parts which were declared to be impossible of manufacture within the degree of accuracy required by the Government Inspectors are now turned out every day. They are interchangeable with one another, and consequently with any spare parts made on the same drawings, a result indispensible, not only for service conditions, but for the proper working of any manufactory on modern lines. Thus is laid the foundation of the constructional power needed to cope with wastage, both in peace and war. It is hard to see why such orders should lead to protests—unless it be that tenders to a Government design are necessarily less profitable than tenders to a proprietary design,

for which there is no competition.

But, quite apart from machines of its own design, the Government purchased in the past year an almost equal number of proprietary machines from British firms. Any suitable machine in the market is tried, and the performances of Government machines set a kind of standard, which the private constructor endeavours to surpass. (It is reported that quite recently a private machine has surpassed, for the first time, a machine of Government design of the same horse-power). Up to the present the number of finished new machines, other than purely experimental, turned out by the Factory has been very small—probably eight machines at the outside for the Army and Navy together.

These comments prompted one private constructor, Mrs H B Hewlett of Hewlett and Blondeau (a short-lived but significant aeroplane manufacturing company), to write to *Flight*, stating that the 'trade' was suffering from its own ruthless competition:

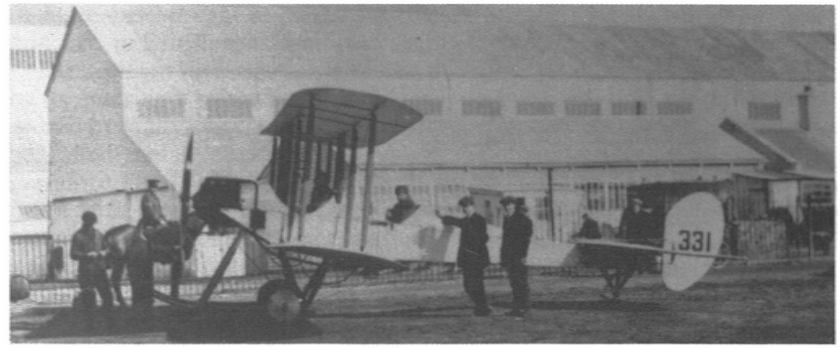
> . . . they are all trying to ruin each other. The rich firms are building machines at a dead loss in order to ultimately get all the orders, so that when they have achieved this they can demand any price they like having once got them. This is, of course, hopeless, as new firms will spring up, and again build for less. If the existing firms would fix a price between them, a fair price that would pay them and pay the Government to get them made out of the Factory, well, and up to the RAF standard, the existing firms would have no reason to grumble . . .

The letter was published on 31 January 1914, together with a lengthy editorial in which the reader was reminded of the campaign of criticism directed, from certain quarters, against the Royal Aircraft Factory, in which it had been alleged that it was the Factory's policy deliberately to undermine the private constructor, a campaign which the editor considered would only be brought to an end if the Factory were not to build machines for the services at all. It was, however, allowed that such a course might not be possible if private firms were unable to deliver machines which were essential for national defence in sufficient numbers, or in time. *Flight* also suggested that Hewlett's letter might explain why so many machines were found, on delivery, not to be of a sufficiently high standard to be accepted and, in consequence, might also explain why the Factory had been forced into a building policy which was foreign to its real functions.

The allegation, made by a rival journal, that the Factory was an open and unashamed pirate of other people's ideas, was examined in great detail and rejected.

Predictably, *The Aeroplane* took an opposing view, and on 5 February asserted, 'The idea that the whole trade is busy cutting its own and one another's throat by cutting the price of B.E. machines is really quite absurd'. Although the excellence of the B.E. design was admitted, the blame for the high rate of rejection was placed upon '. . . inspectors refusing to pass certain things which might very well have been passed . . .', for naturally C G Grey could admit to no fault on the part of the industry.

The continued criticism does not appear to have unduly undermined morale at the Factory, for during January it staged a staff dinner, an event it was hoped to repeat annually. The chosen venue was one of the aeroplane hangars, but, as the weather turned very cold the day before the dinner, a number of portable stoves were collected and placed in the hangar some hours before the event, only being removed at the last possible moment. Thus the hangar was beautifully warm when the guests sat down but, being built of uninsulated corrugated iron sheeting, cooled off rapidly. Before the after-dinner entertainment was over everyone was very cold. Many guests therefore partook freely of whisky and brandy, which at least gave an illusion of warmth, and had an adventurous journey home in the cold night air.



B.E.2a 331 at the edge of Farnborough Common, with the Balloon Shed in the background, 10 February 1914. This machine crashed en route to Netheravon on 15 May 1914.

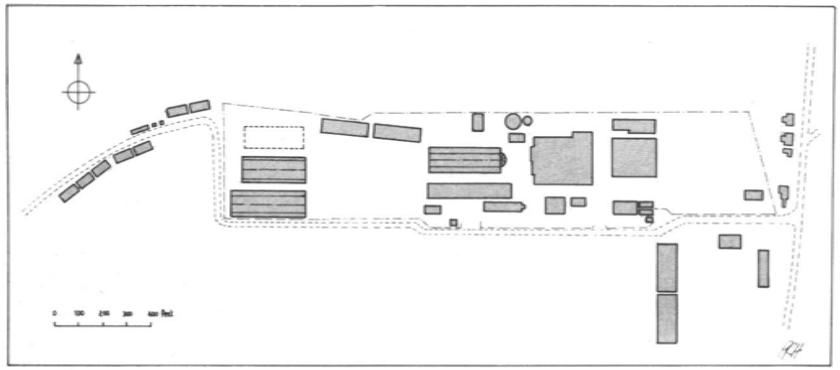
Government paper No 87/2399, published in February and entitled *Tests for Aeroplanes of Private Design*, clearly stated the conditions under which such machines, intended for military use, would be examined at the Royal Aircraft Factory. Intended to establish more consistent standards throughout the ever-growing aeroplane industry, and to forestall further criticism of acceptance standards, this document stipulated that, in order for a machine to be considered for assessment, its manufacturer must first provide stress diagrams proving a minimum factor of safety of six. A pilot and mechanic were also required to accompany the machine.

To quantify the results of such tests, whether for privately-built or Factory machines, the Farnborough staff had devised a set of standard curves for various performance characteristics, including 'speed-resistance' and 'speed horsepower', although their interpretation remained somewhat subjective.

On 23 February Ronald Kemp, the new chief test pilot, was injured and his passenger was killed when the F.E.2 spun into the ground during stalling tests. This tragic accident, which was almost certainly due to the machine having insufficient fin area, marked the end of the 1913 version of the

F.E.2. A new, further revised version emerged later in the year.

Three days later, during a debate on defence, it was reported in Parliament that there was a total of 957 people employed at the Royal Aircraft Factory (compared with 9,546 at Woolwich Arsenal), a figure which demonstrated how much it had grown in recent years. C G Grey, in the next edition of *The Aeroplane*, enquired rhetorically how the presence of such a number was justified in an experimental establishment, especially now that airship development was in the hands of the Navy. Of course it was a large number, but Grey had clearly chosen to ignore the fact that the Royal Aircraft Factory was also now manufacturing aeroplanes, although this aspect of its activities had been the subject of his personal criticism only weeks previously.



ROYAL AIRCRAFT FACTORY, 1914

In addition to development within the Factory compound, the RFC headquarters, including the 'Black Sheds', had been built to the south-east, and a row of flight sheds had appeared to the west, on Jersey Brow.

The Factory's growth was also reflected in the continued capital expenditure upon improvements to the site. In the current financial year a staff messroom had been constructed at a cost of £1,250, £11,300 had been spent on extensions to the workshops, and over £6,000 on the installation of new electric lighting.

The crash of B.E.4 number 204 on 11 March, in which Capt C R W Allen and Lt J E G Burroughs met their deaths, resulted in a temporary ban on the service use of all B.E. types, pending investigation. As this represented over half of the RFC's effective strength, it quickly led to questions being asked in the House of Commons, with Mr Joynson-Hicks welcoming another opportunity to remind the House of what he regarded as the deficiencies in Britain's aerial defences. In answer to a question regarding the construction of aeroplanes by the Royal Aircraft Factory, the House was informed that, although 204 had once been a Bristol biplane, no material of importance, except the engine, was used in its reconstruction into the B.E.4. This was final proof, if such was needed, that the subterfuge

Ill-fated B.E.4 204, which crashed, killing its crew, on Farnborough Common, together with other RFC machines including a Breguet and several Farmans.

of 'reconstruction' had fooled no-one, at least not in recent years. *The Aeroplane*, which devoted considerable space to the debate, ensured that this fact was brought to its readers' attention, claiming that it was a 'gross injustice' to British constructors to claim otherwise.

The accident investigation revealed that 204's fatal crash had been caused by its entering a spin when the rudder shaft snapped, the failure not being caused by faulty workmanship, but by crystallization due to what would now be called metal fatigue. The ban on the operation of B.E. types was therefore lifted, those machines with similar rudders to that of 204 being fitted with new, modified, vertical surfaces before being allowed to fly again.

Although the fault had been found to be due neither to faulty design nor to bad workmanship, as *The Aeroplane* had intimated with its accusation, published on 19 March 1914, that the Factory's designers 'base their calculations on the theories of the armchair airmen of the NPL', no retraction was published, and the incident left the B.E.'s reputation slightly tarnished.

The development of the R.A.F.1 engine had by now reached an advanced stage, and during a bench test on 23 April the prototype ran faultlessly for six hours, producing an average of seventy-eight brake horse-power at 1,800 rpm. During the test it consumed 50½ gallons of petrol, giving a specific consumption of 0.87 pint/bhp/hr, the equivalent figure for oil consumption being 0.055 pints. The engine was then stripped down for detailed examination, and found to be in good condition. It was therefore installed in B.E.2 No 601 for testing in the air, flying trials beginning in mid-May.

The growth of British aviation was illustrated by the production of the Factory's list of civil aeroplanes, which gave a total of 156, arrived at on a similar basis to the previous October's list. The magnitude of the task delayed completion of the list until early May. It included only those machines fully intended for civilian use, and discounted any constructed to Government orders, thus demonstrating an increase of over 50 per cent in a period of six months, a rate of expansion exceeded only by that of the military flying services.

Report and Memorandum No 127, a fairly lengthy document entitled *Precautions taken as to the Strength of details on the B.E. Class Aeroplane*, was published in May, a date which can only have been providential bearing in mind recent allegations regarding the type's safety. The paper described

how the airframe had been tested to destruction so that the true strength of the components could be established empirically. For example, it was found that the wings would withstand eight times their normal load without failure, and that the overall factor of safety was seven.

The machine had been inverted and static-loaded, the weight distribution corresponding to an angle of three degrees of incidence. At a loading equal to three times its own weight it had been found that the rear spar deflected more than the front spar, and a new wing section was designed which permitted a greater depth of spar, allowing the loading to be increased to six times the aeroplane's weight (6*g*) without failure.

Impressive as these factors of safety were, they were perhaps less reassuring than they might appear when the contents of R&M 128 were considered. This publication, prepared by T W K Clarke, asserted that, when a B.E.2 levelled out suddenly after a 'vertical' dive, the load on its wings exceeded 9*g* after a drop of 1,000ft and reached 11½*g* at terminal velocity. What constituted 'suddenly' was not defined, but it mattered little, as only a pilot bent on suicide could be expected to attempt such a manoeuvre, and there is little doubt that the B.E.'s established factor of safety of seven was perfectly adequate. Certainly the War Office remained satisfied with the design, strength and safety of the B.E.2, as it continued to place orders for the type with whichever private manufacturers were able to take them.

So that private designers did not lack the means by which to take advantage of these revelations, R&M 129, which was jointly prepared by O'Gorman and F M Green, was produced to establish a basis for aeroplane design by which it was possible to secure a uniform margin of strength, but its widespread adoption by the industry appears to have been unlikely.

Following criticism that the Factory enjoyed the advantage of possessing test equipment not available to the private constructor, on 15 May *Flight* published the following letter from O'Gorman:

> May I correct in your columns a misstatement accidentally made in another paper? The instruments designed at the Royal Aircraft Factory for aeronautical measurements can be obtained by all who desire so to do. The Velometer is made by Elliot Bros and G Casella. The instrument for measuring gliding angles is made by the Cambridge Scientific Instrument Co, and so is the 'Ripograph' which measures the rolling and other movements of an aeroplane.
>
> Any aeronautical constructor asking how to obtain these instruments has been given the above addresses, and certain firms have had each of the above named instruments in their private use.
>
> The tautness meter was publicly described and is made by the CSI Co.

Although it was uncommon for O'Gorman to write such a letter himself, this was just one of a number of occasions on which *Flight* published letters written by Factory staff, denying or contradicting reports in other publications. Whether the editor's motive in printing these letters was to ensure that the Factory received a fair hearing, or merely to maintain the

controversy in the hope of improved circulation, cannot, of course, be established.

A far less controversial report, published in *Flight* of 25 April, described in great detail the equipment which was to be used to test the engines entered for another aero engine competition hosted by the Royal Aircraft Factory. The arrangements were also described in *The Aeroplane* of 7 May, but in less detail, because the editor must have been aware that many of his readers also took *Flight*. However, the article did say:

> *The Aeroplane* has never yet been suspected of having any undue partiality for the ways of the RAF, therefore it may be as well to record at once an expression of admiration for the extremely businesslike lay-out of the test plant, and for the provision made for accurate measurement of the performances of the various motors.

The very generous first prize of £5,000 attracted twenty-eight entries, and was eventually awarded to another six-cylinder in-line Green engine, this time of 100hp. Like its predecessors, however, although its reliability and economy were praiseworthy, its power-to-weight ratio left much to be desired, and little use was made of it. It was obvious, therefore, that improved engines of higher outputs were urgently required. Although the Factory staff continued to work on engine development with unabated endeavour, interest from private firms was slight, and it took much persuasion to get the more successful motor-car manufacturers, such as Rolls-Royce and Napier, to consider aero engine production.

On 19 May their Majesties King George V and Queen Mary again visited Farnborough, when they witnessed a demonstration of the inherently stable R.E.1, piloted by its designer, E T Busk. The behaviour of this machine made a considerable impression upon all who saw it, especially those witnessing it for the first time. The flight, and the Royal visit, were reported at length in the following day's edition of *The Times* beneath a headline

E T Busk seated in his first stable aeroplane, the R.E.1, seen here with experimental fin surfaces above the upper wing.
(Imperial War Museum)

which read, 'Safe Flying—A New Stable Aeroplane—Flight Without Control—The King's Visit to Farnborough'. The action of the machine was described thus:

> . . . On turning the rudder right or left the aeroplane turned right or left, in each case taking up its own appropriate 'bank' suitable for the sharpness of the turn. Gusts caused the aeroplane to rock, but without personal intervention it resumed its proper attitude of flight. When the engine was cut off it took its own angle of gliding flight; when the engine was opened up fully during the glide the aeroplane gained speed and then immediately moved on to the upward path—a partial closing of the throttle brought the machine on to a horizontal course. We may congratulate ourselves that these events first occurred in England, and that the aeroplane is a product of the Government's Royal Aircraft Factory at Farnborough.

This development was clearly viewed as being of great benefit, bringing improved control and increased safety to aeroplane flight, with the layman, personified by the *Times's* correspondent, sharing the Factory's belief in its advantages. The attendant disadvantages were not realised until they were painfully demonstrated in aerial combat.

At the end of the month Busk made the first flight of the machine which represented the culmination of his devotion to inherent stability, the B.E.2c, a development of the basic B.E.2 which incorporated a great deal that had been learned as a result of numerous experiments with earlier designs, most notably the R.E.1. The B.E.2c resembled a cross between that aeroplane and the original B.E.2. Its wings were staggered, and incorporated ailerons for lateral control. A triangular fin had been added, and a new non-lifting tailplane of higher aspect ratio had been substituted for de Havilland's original.

Although there was no longer any need for it, the habit of 'reconstruction' was now so much a part of Farnborough tradition that the prototype B.E.2c

A production B.E.2c built by Hewlett and Blondeau, one of twenty or so contractors who undertook its manufacture.

was converted from an earlier machine, No 602, a great deal of which would have been scrapped or returned to stock as spares during the course of its conversion.

The B.E.2c's superiority over previous designs, particularly in meeting the requirements of the Army as they were then understood, virtually guaranteed its being ordered into production from a variety of private manufacturers. In service use it soon acquired the nickname *Stability Jane* and, a little later, the *Quirk*. In view of the controversy which would later surround this aircraft, and the ill-favour with which it eventually came to be regarded, it is worth recording that, when judged by the standards of its day, its performance was respectable, its safety was assured by detailed research, and its stability was a positive advantage for the unopposed reconnaissance which both its creators and its operators saw as its rôle.

On June 9 the prototype B.E.2c was flown from Farnborough to Salisbury Plain by Maj W S Brancker, who demonstrated the utility of its inherent stability by allowing it to fly 'hands-off' while he wrote a reconnaissance report on the country over which he was passing. At that time virtually the whole of the front-line strength of the Royal Flying Corps was gathering in a 'Concentration Camp' on the Plain, and all personnel present expressed a keen interest in Brancker's mount. Many of them, no doubt, realised that they would soon get an opportunity to fly such a machine themselves, for almost half of the machines there were Factory designs.

Another significant new design which was 'unveiled' during June 1914 was the S.E.4, a single-seat scout which had a phenomenal maximum speed of 135mph—greater than the officially recognised world record. This was as much due to its carefully streamlined form, the result of lengthy windtunnel research, as it was to its two-row Gnome rotary, for which a power output of 160hp was usually claimed. A fan was fitted inside its large propeller spinner to assist in cooling the engine, which was enclosed within a neat cowling. The biplane wings were braced by single interplane I-struts, in accordance with a patent (No 22,493) taken out the previous year by F M Green, and the gaps between control and fixed surfaces were faired over with elastic netting to eliminate turbulence. The full-span ailerons could also be operated in concert to reduce the landing speed by 5mph, giving rise to the claim that they were the first flaps. A celluloid canopy was designed to improve streamlining by enclosing the cockpit, but, although it was manufactured it appears never to have been used, simply because no pilot would fly the machine with it fitted. Testing was largely undertaken by Norman Spratt, a fairly recent recruit to the Factory's staff of test pilots.

Another test pilot who had joined the Farnborough team that spring was Frank Goodden, a young man who had previously made balloon and airship trials and had already taken part in the Hendon flying displays. Goodden had only taken his *brevét* the previous summer, and his rapid rise from tyro to expert testified to his own natural skill and the rate of expansion in aviation generally.

July saw the completion of the Factory's latest venture into aero engine design, the R.A.F.3, which was now subjected to the lengthy process of

bench-testing and development necessary to achieve consistent output and reliability. It was a water-cooled twelve-cylinder vee type, the included angle between the cylinder banks being only 60°, in order to reduce the frontal area as much as possible. Designed to deliver 200hp, it had a 2:1 ratio geared drive to the propeller, a feature which allowed the use of a high crankshaft rotational speed and gave increased power from a given cylinder capacity without loss of propeller efficiency. Unfortunately reduction gear design was in its infancy, and the R.A.F.3, like many geared engines of the period, was never as reliable as ungeared types. It did, however, offer the promise of sufficient power to encourage the design of larger and heavier aeroplanes.

The outbreak of war on 4 August found Britain's air services still woefully under-equipped, and while it was promptly decided that all landplanes then available should be assigned to the RFC and all seaplanes to the RNAS, the major stumbling block to increased aeroplane production was the dire shortage of suitable engines. Those which could be found were distributed to the armed forces, almost all of the low-powered units (less than 100hp) becoming the property of the Army, and the higher-powered engines going to the Navy, which needed more power for its large seaplanes.

However, power outputs in excess of 100hp were still very rare, and a number of motor manufacturers, including Rolls-Royce and Napier, were instructed to produce such engines. To assist them in their endeavours the drawings of the R.A.F.3 were made available, and although Rolls-Royce chose to develop its own designs instead, the Napier Company eventually put the engine into production.

Farnborough's most advanced project so far, the F.E.4 twin-engined pusher biplane designed by S J Waters and H P Folland and having many novel features, was shelved in favour of a further remodelling of the F.E.2, this being considered capable of more rapid development. The new version followed the same basic layout as previous bearers of that designation, but was the largest yet. Following the policy of standardisation of components practised at Farnborough, the new machine had wing panels identical to those of the B.E.2c, which, attached to the new pusher's wide centre section, gave it a wing span of over forty-seven feet. Features designed to prevent a recurrence of the stall/spin which had caused the fatal crash of the previous model included an increase in the chord of the tailboom struts, and the covering of the triangular kingpost above the tailplane with fabric, both changes serving to add to the keel area aft of the centre of gravity. This was made all the more necessary by the repositioning of the nacelle further forward, to improve the crew's field of view. The engine initially selected was the 100hp Green, winner of the recent competition. Although it was seriously overweight for its rated power and barely adequate for so large a machine, it was the only powerplant available.

From its inception the F.E.2a had been designed to carry a machine gun and, owing to the mood of urgency and aggression normal in time of war, and the desperate need for aeroplanes of any type, it was rushed into production before a prototype could be built. As it was effectively the fourth machine in a development series, and its behaviour could be safely anticipated, this was

not as foolhardy as it may appear. In fact, the Military Aeronautics Directorate, the War Office department responsible for the provision of equipment for the RFC, had decided that the planned expansion of that service, which had already made a valuable contribution to the progress of the war, would necessitate the purchase of large numbers of new aeroplanes. The quantity envisaged was so great that it was considered doubtful whether the existing aeroplane manufacturers would be able to cope. Despite their own massive rates of expansion many were already struggling to fulfil existing orders, and a number were concentrating solely upon machines of their own design.

Unlike many of the private companies, the Royal Aircraft Factory produced fully detailed drawings for each individual component in its machines, and a full set for any aeroplane type therefore totalled many hundreds of separate drawings. In addition to being sound engineering practice, the production of such drawings enabled companies new to aeroplane manufacture to produce component parts or even entire machines. Thus the War Office was able to order B.E.2cs, at a standard price of £1,072-10s-0d each (less engine), not only from established aircraft companies, but also from furniture manufacturers, motor vehicle and carriage builders, agricultural engineering companies, and any similar company with the necessary workshop space and skills. The only disadvantage with such diffused production was the difficulty, and inevitable delay, in keeping manufacturers advised of any detail changes necessitated by the development of aerial warfare.

B.E.2cs of 13 Squadron at Gosport on 12 October 1915, en route for France. Aircraft 2017 was built by Armstrong Whitworth, 4084 and 4079 by the British and Colonial Aeroplane Company, and 2045 by Daimler. The difference in serial styles is noteworthy.
(13 Squadron records, via PHT Green)

On Thursday 5 November 1914, before the first of the eventual multitude of mass-produced B.E.2cs could be completed, the type's creator, Ted Busk, met his death when the Farnborough-built example he was piloting, No 601, caught fire in the air and crashed on Laffan's Plain. The cause of the fire is usually attributed to a leaking petrol tank, but it has also been suggested that Busk was conducting tests of a newly developed incendiary bomb which malfunctioned and started the blaze, and that the petrol leak was a cover story designed to prevent the public, or the enemy, learning of the new secret weapon. Whatever the cause, the result was the same. Busk

The burnt-out remains of the B.E.2c in which Edward Busk perished.
(Royal Aerospace Establishment)

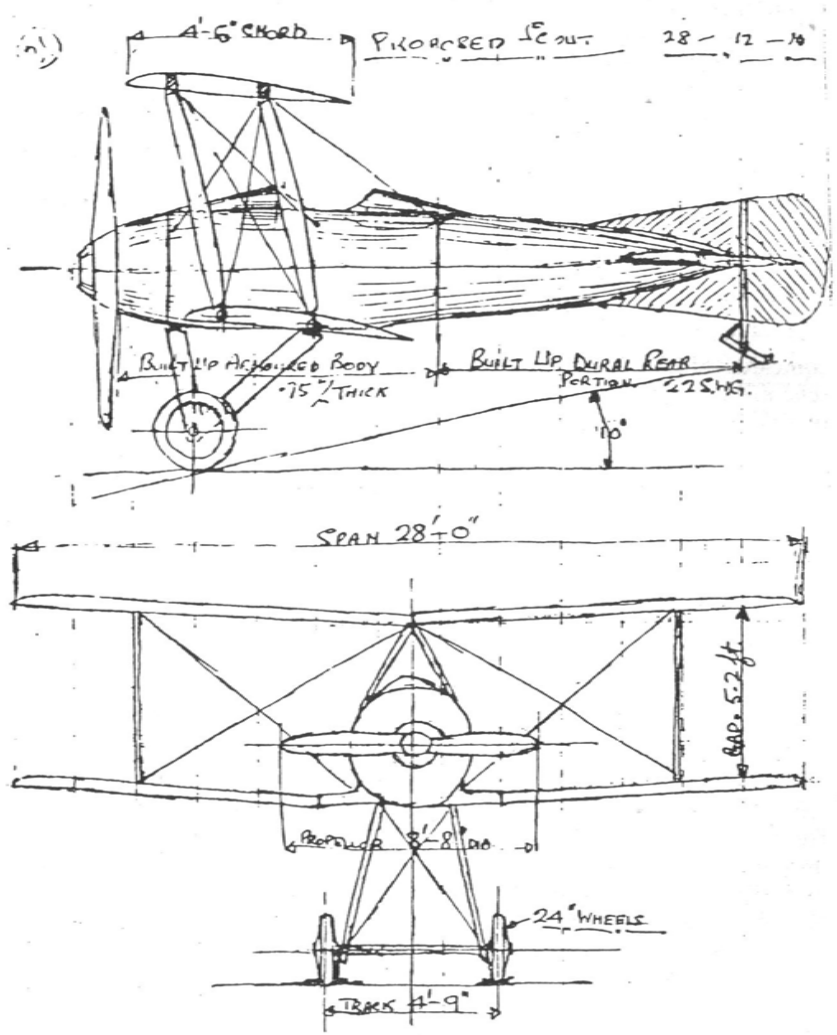
was dead, and he was buried four days later in Aldershot Military Cemetery, close by the grave of S F Cody, who had become the first civilian interred there following his own tragic crash, also on Laffan's Plain, on 7 August the previous year.

Busk was sorely missed both for his cheerful, self-effacing personality and for his clear vision and engineering ability. But the work of the Factory had to continue, and the projects on which he had been working were taken over by R H Mayo. Equally essential was the urgent replacement of the prototype 90hp R.A.F.1a engine which had been under test in Busk's aeroplane at the time of the crash, which it was intended to put into mass production to power future examples of the B.E.2c.

Concurrently with its re-creation of the eight-cylinder R.A.F.1a, the Factory began work on an air-cooled V-12 designed to develop about 150hp. This engine, the R.A.F.4, was created by the simple expedient of designing an extended crankcase to which were fitted twelve of the R.A.F.1a's cylinders, complete with pistons, connecting rods and valve gear. Because the new engine was based so closely on an existing, and to some extent proven design, it was fairly rapidly brought to a stage of development which enabled it to be placed into production, providing a much-needed addition to Britain's range of aero engines.

The virtually static trench warfare which had become established along the Western Front led to the setting-up of semi-permanent aerodromes as bases for the RFC squadrons operating there. In response to the obvious need for some kind of shelter to protect aeroplanes from the weather, and to facilitate routine maintenance and repair, the Royal Aircraft Factory designed a number of portable hangars. The first of these, the R.E.7 type, was designed to house one machine of that type, but could house up to three smaller machines if they were carefully stowed. Measuring sixty feet long, thirty feet deep and twenty feet high, each R.E.7 hangar weighed only sixteen hundredweight (1,800lb), enabling them to be packed three to a lorry. Although some 600 examples were eventually produced and deployed, they were found to be unequal to the extremes of weather, tending to sag in heavy rain, with the risk of damaging the aeroplanes they were intended to protect.

The RAF Heavy pattern, designed to overcome this deficiency, was fifty-three feet by forty-three feet deep, and offered much better protection for up to five machines. However, it weighed over 2 ½ tons and required a lorry to move it.



This sketch in H P Folland's notebook, dated 28 December 1914, depicts an armoured scout based on the S.E.4a.

On the more permanent aerodromes the Factory-designed hangars were frequently replaced by the larger French Bessonneau, which could accommodate up to eight scouts but was far less portable as it weighed some 8½ tons and needed five or six lorries to transport it. However, in the more temporary rôle for which it was designed, the Royal Aircraft Factory hangar continued in use until the end of the war and the return to permanent bases with timber or steel hangars.

Although no specific request had yet been received from the War Office, the Factory's design team had already begun to think in terms of an armed 'scout', combining the speed and agility of the single-seater with the firepower which was then only available in two-seaters, usually pushers. This investigation resulted in the production of drawings A5246 to A5249, dated December 1914, which detailed the installation of a Lewis gun on the S.E.4a, a neat single-seater designed by Henry Folland earlier that year. The gun was to be mounted on the upper centre section, firing over the propeller disc, its trigger being operated via a cable. This arrangement had several drawbacks. The gun was out of reach of the pilot, who would therefore find it difficult to reload or clear stoppages, and the line of fire coincided with the pilot's aim at only one precise range. Consequently this scheme, in common with a proposal to equip the aeroplane with armour plating for protection against small-arms fire from the ground, failed to attract official interest and was shelved.

Patent, No 8862, filed during 1914 by two members of the Factory staff, chief draughtsman S W Hiscocks and S J Waters, described an aeroplane having twin fuselages attached to a common set of wings and stabilising surfaces. It was taken up early in the new year by the Blackburn Aeroplane Company, which proposed an inherently stable seaplane utilising two B.E. fuselages in precisely the same manner. However, by the time the design of the machine was completed as the Blackburn TB, only the fins and rudders gave any clue as to the type's origin.

This was only one of several occasions on which components or assemblies from Factory machines, particularly the B.E.2c, were incorporated into privately designed aeroplanes. Sadly such co-operation between the Royal Aircraft Factory and private industry did little to stem the flow of criticism from the Factory's enemies, the principal one still being C G Grey. Even in articles describing the products of the industry, Grey managed to infer criticism of the Farnborough establishment and its staff, achievements or products, frequently making unfavourable comparisons. He ignored the Factory's own discoveries or advances, or erroneously attributed them to a later industry source. Any favourable report of Farnborough activities in other publications prompted a renewed attack by Grey, a typical example being: 'Could anything be more grotesque than the attempt to standardise upon, and order in large quantities, a machine which admits in its own official title that it is only an experiment, for B.E. stands for Blériot Experimental'.

While it is believed that Grey was motivated by a fervent belief in the merits of private enterprise, coupled with a total lack of faith in officialdom, and was therefore acting in what he sincerely believed to be the best

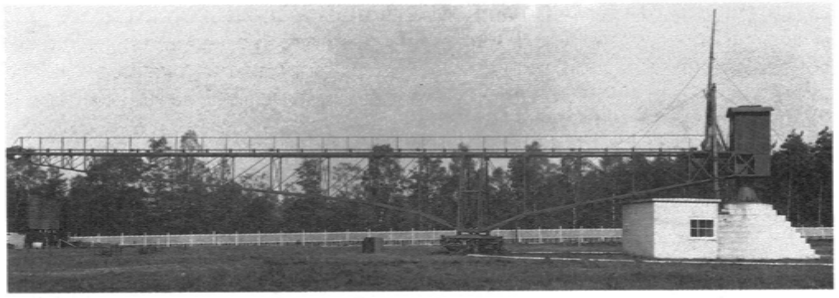
Factory employees leaving the South Gate for lunch, circa 1915.
(JM Bruce/GS Leslie)

interests of the British nation in general, and its aircraft industry in particular, he was, nevertheless, sowing seeds of doubt in many minds.

Despite these criticisms the Factory continued its work, and entered a new phase of development and expansion in order to meet the additional demands placed upon it by the war. An additional workshop was built, additional staff were engaged and, since the workforce was now far larger than the area could normally support, a group of houses, known as Pinehurst Cottages, were constructed to provide accommodation for workers from outside the district.

In February 1915 a new unit, not forming part of the Factory, was established at Farnborough for the repair of aircraft which were damaged too extensively for repair by local RFC units. The new unit, which was named the Southern Aeroplane Repair Depot (SARD), took over the ten aeroplane sheds on Jersey Brow as well as the two airship sheds at the western end of the Factory site, which had become surplus to requirements since the Navy had taken over airship operation. The portable airship shed, which was not only no longer required but had been damaged in a gale the previous year, was dismantled. Its steelwork was re-used, with corrugated iron cladding, to provide further workshop accommodation elsewhere on the site, thus leaving the area clear for the SARD.

The report of the Advisory Committee for Aeronautics covering this period says that the work of the Royal Aircraft Factory included windtunnel tests on a wide variety of components such as struts, bracing wires and



The huge whirling arm which was used to test full-scale components, such as propellers, which were too big for the windtunnels. It occupied much of the eastern end of the Factory site from its completion in mid-1913 until it was dismantled some three years later.
(Royal Aerospace Establishment)

undercarriages. In addition to developments in aeroplane stability and continuing investigations into the causes of spinning, it was recorded that O'Gorman's staff had developed or improved a number of aeroplane instruments. Research into engine supercharging and into variable-pitch propellers was already under way, and Dr J E Ramsbottom, the inventor of the hydrogen-resistant Delta Dope coating, had developed a new 'dope', designated P.C.10 (Protective Covering, specification No 10), which resisted the deterioration of fabric caused by the actinic rays in sunlight. This was adopted for aeroplanes supplied to the RFC, its green-brown hue quickly superseding the pale cream of clear varnished fabric which had previously been the normal colour of service aeroplanes. Another similar product, P.C.12, was later developed as an alternative, its red-brown colour proving to be a more effective camouflage in the Middle East theatres of war, although its use on the Western Front was not unknown.

The War Cabinet's continued faith in the Royal Aircraft Factory, despite repeated criticism from C G Grey, was demonstrated on 7 April 1915, when Lord Kitchener, the Secretary of State for War, sent a message of encouragement for the attention of all the Factory staff.

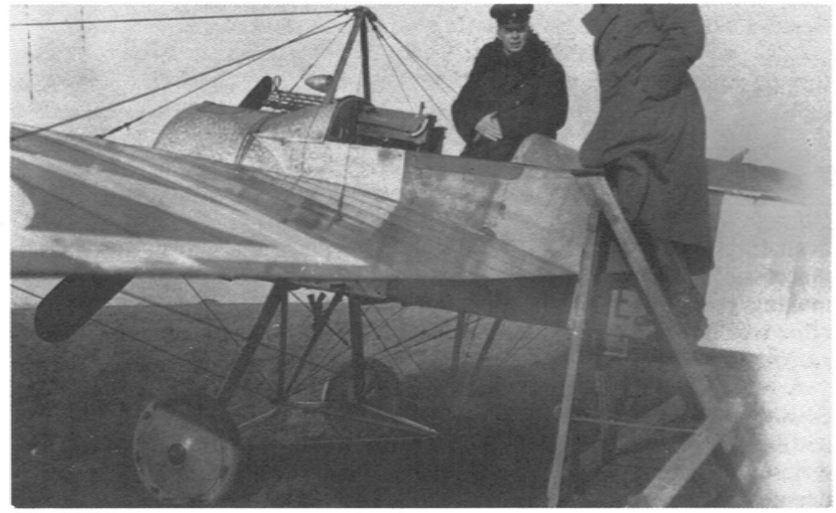
A new recruit arrived on 1 May. This was William S Farren, who had been appointed chief aerodynamicist and who was, many years later, to become Director of the RAE.

During the summer of 1915 the combination of mankind's inventiveness and his natural aggression finally produced the true fighter aeroplane, a fast single-seater armed with a forward-firing machine gun which could easily be sighted upon its prey without the need to consider relative angles or parallax. The gun was mounted directly in front of the pilot, within easy reach for loading or correcting malfunctions, and had an effective interrupter gear which prevented the bullets striking the propeller blades. Unfortunately for the Allies this device was first perfected in Germany, and a handful of such fighter aircraft, the delicate Fokker monoplanes, caused havoc among their opponents, many of which were still virtually unarmed.

W Sholto-Douglas (later Lord Douglas of Kirtleside) stated in his

autobiography* that, at that time, '. . . the RFC had not yet progressed much beyond the two-seater general purpose aeroplane, the best of which was still the B.E.2c'. The B.E.2c, with its pilot in the rear cockpit and observer in the front, surrounded by struts and wires and often armed with nothing more than a service rifle, fared no better than could be expected, and flying suddenly ceased to be a sport.

Described by the popular press as the 'Fokker Scourge', this setback in the fortunes of the RFC obviously provided further ammunition for C G Grey's campaign against the Royal Aircraft Factory. He held the Factory responsible for the sudden and unexpected obsolescence of its most numerous creation, choosing to ignore the fact that it was ordered and operated by the RFC, not by the Factory.



The cause of the 'Fokker Scourge'. A Fokker *Eindecker* with the German 'Ace' Oswald Boelke in the cockpit. The forward-firing machine gun which made it such a feared adversary is clearly visible.
(JM Bruce/GS Leslie)

That a number of front-line aircrew seemed to find some satisfaction in referring to themselves, or their machines, as 'Fokker fodder' seems to have been due more to delight in the phrase's alliterative allure than to any actual anxiety over their increased chances of being shot down, an attitude which tends to suggest that their morale was largely unaffected by the change in the odds.

Design staff at the Royal Aircraft Factory were well aware that the B.E.2, the basic design of which was already more than four years old, was due for replacement, and that its successor would need not only improved performance, but reversed crew positions to allow its observer/gunner a

* *Years of Combat* (Collins, London, 1963).

reasonable defensive field of fire. They knew, too, that, even in those less sophisticated days, effective new aeroplanes were not designed overnight. The most expedient solution, it seemed, was to do as much as possible to enhance the abilities of existing aeroplanes, particularly the B.E.2, while work on new designs was proceeding. It is unfortunate that their efforts met with only minimal success, but it is unfair that they should be blamed for making the effort. Unlike a private company, the RAF had no financial interst in the continued use of a particular design, its only motive being the prevention of further loss of life.

While the attitude within the Factory remained one of urgency, pursuant to the needs of war, it was far from being one of panic. When it was realised that the staff needed a break after working non-stop for a year, the Factory was closed for three days from 6 August, acknowledging the traditional Bank Holiday weekend and allowing the staff to relax.

In September *The Times Engineering Supplement* expressed its support for the mass-production of the B.E.2c, which, although now somewhat outdated, it regarded as a proven and reliable design which was still among the best aeroplanes available. Needless to say, C G Grey's *The Aeroplane* disagreed.

Meanwhile, efforts to produce a fighter aeroplane to counter the Fokker continued with increased energy but, as no synchronisation gear was yet available, British designers were obliged to place the gun in awkward or inaccessible locations to enable it to fire clear of the propeller, thereby making reloading difficult, or to retain the pusher format to gain an effective field of fire, thereby accepting the attendant reduction in performance.

A possible alternative layout which it was thought might combine the advantages of both tractor and pusher, without their respective deficiences, had been conceived as far back as mid-1914. However, it was so radically different to previous designs that extensive windtunnel research was deemed necessary, first to ascertain the feasibility of the proposal, and then to determine the best layout. In accordance with the Farnborough tradition of not building prototypes from scratch, the resulting aeroplane, the B.E.9, was created by converting a standard production B.E.2c, No 1700.

The engine was moved back to occupy the space normally taken by the observer's cockpit, which was relocated in front of the propeller, and took the form of a plywood nacelle supported on a ball-bearing mounting on the forward end of the propeller shaft and a system of struts from the undercarriage legs, and braced by four wires running out to the wings. The new engine position required the cabane struts to be raked outwards to clear the cylinders, resulting in a wide centre section, to which standard B.E.2c wing panels were attached.

This unusual arrangement gave the observer an enviable field of fire without serious loss of performance in comparison with a conventional tractor design of similar size and power, although communication with the pilot was all but impossible. The derivation of its irreverent nickname, *The Pulpit*, is obvious. Equally obvious was the unfortunate fact that, despite a fairly favourable report from pilots at the Central Flying School, it was not a

The B.E.9 is shown to HM King George V during his visit to Farnborough on 18 August 1915.

viable answer to the RFC's problem, and trials were eventually discontinued.

A far simpler solution to the problem was found by modifying the design of the big pusher F.E.2 to simplify manufacture, and placing it in mass production. A variety of manufacturers as diverse as those already building the B.E.2c eventually produced it. Although it was not quite as speedy as the Fokker it proved an effective opponent, and, together with the rather similar Vickers Gunbus, did much to redress the balance of power in the skies over the Western Front.

However, the RFC still needed a single-seat fighter (or 'scout' in the terminology of the day) to take the fight to the enemy. Farnborough's main contender, the F.E.8, which was designed by John Kenworthy, was fairly similar to its principal rival, the Aircraft Manufacturing Company's D.H.2, for which Geoffrey de Havilland was responsible. Both were powered by 100hp Gnome rotaries and both were, of necessity, pushers of similar size, although the Factory's design had a slightly greater span and higher aspect ratio. The F.E.8's tailbooms met at the tailplane spar, rather than at the sternpost, as was more common.

The first flight was made by Frank Goodden on 15 October, and the machine was found to fulfil all expectations. Although it was marginally faster than its rival, and in no way inferior, production problems unfortunately delayed the F.E.8's entry into service until the middle of the following year, by which time time it was already virtually out of date, a fact

which could only add to the dissatisfaction of the Factory's critics.

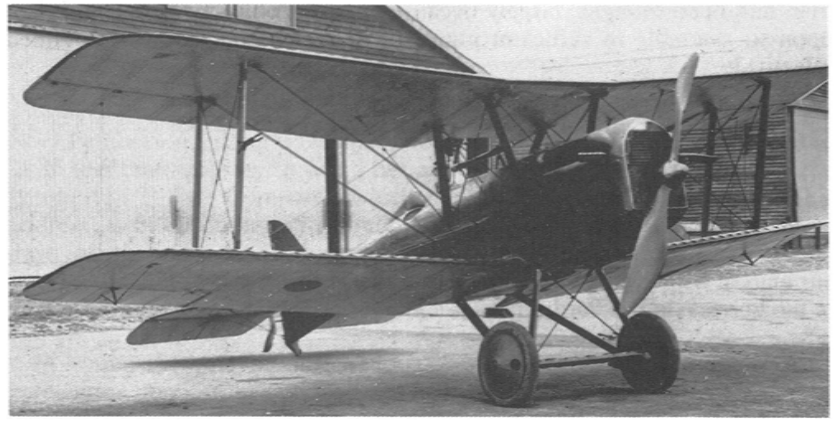
In October 1915 previous policy regarding the Royal Aircraft Factory's civilian status was modified to prevent the loss of key personnel to more mundane military units. Thus, when the Hampshire Parks RFC(T) Reserve was formed at Farnborough, almost 1,600 men from the Factory staff took military rank. Not unnaturally Mervyn O'Gorman became the unit's commanding officer, with the rank of Lieutenant Colonel, a rank which his predecessors, Templer and Capper, had enjoyed while in command of units of much more modest size. Heads of departments such as S W Hiscocks, W S Farren and F M Green became captains, while S Heckstall-Smith, the Assistant Superintendent, and a few other key personnel became majors, the remainder of the technical staff being subalterns.

Towards the end of the year, in an effort to ensure that all aircraft designers had full knowledge of current military requirements, the Factory hosted what might today be called a seminar at which the RFC's policy, plans and proposals regarding future needs were discussed. O'Gorman took advantage of the opportunity to reiterate his assurances that, while it was working towards common goals, the Royal Aircraft Factory was not intending to compete with the industry. Prototype and experimental machines would continue to be built in the Farnborough workshops, but it was intended that any Factory-designed aeroplanes selected for use by the RFC would be manufactured by any private contractor able to accept such orders, the Factory only undertaking volume production when it was clear that private companies could not cope with the volume of orders received. Naturally the responsibility of making such selections remained with the War Office, the Factory offering its designs for assessment in the same way as private manufacturers.

The design of any new aeroplane often starts by selecting the appropriate powerplant, and the arrival of a new engine spurs aeroplane designers to create new vehicles to take advantage of it. Among the most innovative engines of the period was the water-cooled 150hp Hispano-Suiza V-8, the prototype of which had first run in the summer of 1915. Its power-to-weight ratio, compactness, and efficiency were all outstanding, but production facilities were limited and the French, in whose country the engine was produced, felt that their needs should be met in full before allowing sales abroad, even to their allies. By early 1916, however, determined negotiations had secured Britain the right to manufacture the engine under licence, and key Factory personnel met in O'Gorman's office to discuss the uses to which it should be put.

A plan to transform the B.E.2 by substituting the Hispano-Suiza for its 90hp R.A.F.1a was considered and abandoned only after several experimental installations had been made. What the RFC needed as much or more than a revitalised B.E. was a truly effective single-seat scout, so two alternative designs, each powered by the new engine, were prepared. One, the F.E.10, was a pusher, and the other was a small tractor, for which no gun synchronisation system was yet available. The former was never built, the latter became the S.E.5.

The battle with enemy fighters was far from being the only aspect of war



Designed around the Hispano-Suiza V-8 engine; the Factory's pugnacious S.E.5.

with which the RFC and the Factory were concerned. One of the Factory's contributions to the struggle against the Zeppelin raiders was the 'Fiery Grapnel', which was designed to be carried on an aeroplane's undercarriage and to be released above an enemy airship. It comprised a three-inch-diameter tube about eight feet long, to which was attached a barbed head made of steel tubes, stiffened with metal fins, which was intended to catch in the fabric of the airship envelope. The tube was packed with explosive which was detonated by a pull fuse attached to the line by which the weapon was suspended from the attacking aeroplane. It was tested in the early days of 1916, but was not adopted, principally because airships were already operating at altitudes which contemporary aeroplanes found difficult to reach, and they were thus unable to climb above the raiders to release the weapon.

A far more successful weapon designed by the Factory was a new bomb designed for use against aircraft hangars, concentrations of vehicles, and similar 'soft' targets. Seventy pounds of high explosive was contained within a heavy casing, producing a bomb with a total weight of 336lb which, when detonated, threw out jagged fragments of casing in all directions at speeds of up to 2,000 feet per second, causing considerably more damage than a conventional bomb of similar size.

A range of more conventional bombs of up to 520lb, whose explosive content represented a higher percentage of their total weight, was also designed. These were adopted by the RFC for attacks upon targets such as buildings, although their manufacture was undertaken by the established munitions industry.

However, the Farnborough workshops did undertake the manufacture of *fléchettes*—metal darts designed to be dropped from aeroplanes on to massed troops. The design produced by the Royal Aircraft Factory comprised a pointed steel nose attached to a tail of brass tubing. Manufacture ceased when it was realised that they were far less effective

than had been thought, largely because enemy troops could not be relied upon to assemble in sufficient numbers to enable the darts to be aimed effectively.

Enemies in high places

Noel Pemberton Billing was a flambuoyant individualist. He had learned to fly in less than one day to win a bet and, before the war, had founded the Pemberton Billing Company, which had 'Supermarine' as its telegraphic address, with the intention of building improved flying-boats. In the early days of the war he had served, with some distinction, as a Flight Sub-Lieutenant in the Royal Naval Air Service, and had helped to plan the daring bombing raid on the Zeppelin base at Friedrichshafen, carried out at Christmas 1914.

In March 1916, having resigned his commission, he successfully fought a by-election to become the Independent Member of Parliament for East Hertfordshire, and almost immediately embarked upon a campaign of criticism of the management of Britain's flying services. Thus, in a speech in the House on the 22 March, he stated:

> I do not intend to deal with the colossal blunders of the Royal Flying Corps, but may I refer briefly to the hundreds, nay thousands of machines which have been ordered and which have been referred to by our pilots at the Front as 'Fokker Fodder'? Every one of our pilots knows that, when he steps into one, if he gets back it will be more by luck and by his skill than by any mechanical assistance he will get from the people who provide him with the machines. I do not want to touch a dramatic note this afternoon, but if I did, I would suggest that quite a number of our gallant officers in the Royal Flying Corps have been rather murdered than killed . . .

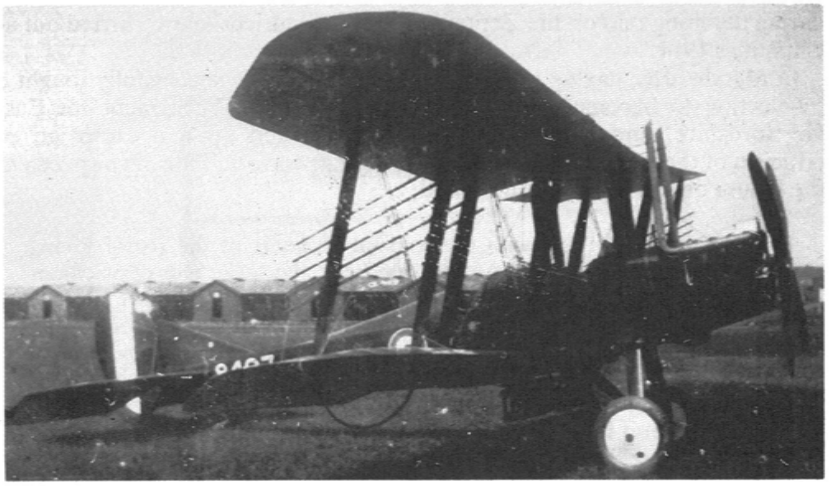
This sensational accusation, although directed, properly, at War Office policy, was interpreted by many people as also inferring criticism of the Royal Aircraft Factory and of the B.E.2c, and added to the industry's resentment of its supposed rival.

Later, during a debate on the Air Services, Billing elaborated upon the same theme:

> . . . if the officials who are responsible for deciding the type of machines in which our officers are to take to the air fail either by ignorance, intrigue or incompetence, to provide them with the best machines that this country can produce, they are guilty of a crime for which only a fastidious mind can fail to find a name.

This was another sensation-seeking outburst which totally missed the point of the matter, for while many people still considered that the B.E.2c, at which the attack was obliquely directed, was the 'best machine' available, few would deny that it was no longer quite good enough. A replacement was being sought, but none was, as yet, available. But Billing was far from finished, and continued, saying:

Our machines are dispatched in most cases as aeroplanes only. On their arrival the local squadron smiths do their best to convert them into weapons of war. A gun is stuck on here and a bomb hung on there. The performance of the machine loses ten to twenty per cent of its efficiency. For example, the official speed of the B.E.2c is something less than eighty miles an hour. That in all conscience is bad enough when the machine is called upon to fight a Fokker, or other German aeroplane with a speed of 110 miles an hour, whereas by the time it has been turned into this travesty of a weapon of war, its speed is reduced to about sixty miles an hour . . .



'A gun is stuck on here and a bomb hung on there . . . '; a B.E.2c loaded with a 112lb bomb (below fuselage) and eight Le Prieur rockets, with obvious detriment to its already poor performance.

That he had greatly exaggerated both the Fokker's speed, which was actually less than ninety miles per hour, and the degree by which the B.E.'s speed would be reduced when carrying the additional load described, was almost immaterial. The point that he had failed to mention was that the Fokker was effectively armed and the B.E.2c, like all similar British machines, was not.

However, unhindered by any particular desire for accuracy, the MP pressed on to his conclusion:

> . . . with regard to the men who have died, they can in most cases be referred to as 'Fokker Fodder'. In almost every case they have been shot down in hopelessly outclassed machines by the immensely superior machines which the Germans are bringing against them.
>
> We are prepared to order machines from the Royal Aircraft Factory with engines unproved and untested and order pilots into the air to meet their deaths. Those men who have only been wounded owe their lives to

> providence, despite official negligence and incompetence, but the missing in all cases have been lost to this country on account of dud machines or inefficient engines.
>
> I would suggest that no time should be wasted and an immediate inquiry be made into this charge.

Thus Noel Pemberton Billing demonstrated not only his concern for the welfare of British airmen, but also his enmity towards the Royal Aircraft Factory in general, and the B.E.2c in particular. Although his opinions were far from being balanced or unbiased, his experience both as an aircraft manufacturer and as a naval aviator endowed them with an air of authority which many found totally convincing. Lord Northcliffe's *Daily Mail* soon echoed Billing's remarks, and C G Grey, a good friend of his, was not slow to rally to the cause.

During this same Parliamentary debate it was stated that the total number of employees at the Royal Aircraft Factory had grown enormously since the outbreak of war. Design staff, for example, who had numbered only six in 1910, now totalled 275. It was also reported that, since a great percentage of the Farnborough staff were women, the Factory was not popular with many local residents, because it paid higher wages than they were prepared to, and thereby brought about a shortage of domestic servants.

Although Billing's use of the word 'murder' was later dismissed as an 'abuse of language', and the remainder of his accusations may not have been totally founded on fact, they had the intended result. On 30 March the Army Council announced the appointment of a Committee, under the chairmanship of Sir Richard Burbidge, which was:

> To enquire and report whether, within the resources placed by the War Office at the disposal of the Royal Aircraft Factory, and the limits of the War Office order, the organisation and management of the Factory are efficient, and to give the Council the benefit of suggestions on any points of the interior administration of the Factory which seem to them to be capable of improvement.

The Burbidge Committee, as it became known, acted with commendable speed. On 12 May, only six weeks after its appointment, it completed its report, although publication was deferred until it could be considered by the Army Council who had commissioned it.

This report described the internal organisation of the Factory and the work carried out there in some detail, and included the information that the only actual manufacturing work done since the outbreak of the war had been the construction of about fifty non-experimental aeroplanes and the manufacture of spare parts to meet urgent demands. Numerous orders had been received for the latter and, although in most cases the quantities were small, the aggregate total represented a fair percentage of the Factory's total turnover.

The report also stated that the total number of people employed on 26 March 1916 was 4,222, and that the total weekly wage bill amounted to

approximately £10,500. It criticised the administrative systems as being 'over-elaborate', and suggested that the percentage of staff employed in non-productive departments such as the General Office and Stores was far too high, especially as stock control often left something to be desired despite their presence, and it was not unknown for the Factory to run out of specific materials.

The committee's conclusions were that an establishment such as the Royal Aircraft Factory was necessary, and that the standard of efficiency required of it by the War Office was being met. It was felt that the salaries offered to heads of departments and others of high ability were too low, and unlikely to benefit recruitment or retention of well-qualified personnel, and that the work done by the staff merited more consideration than it had hitherto been given.

In accordance with its terms of reference, the committee's report included the following recommendations:

> That a board of management be formed consisting of a Chairman or Director of the Royal Aircraft Factory, a superintendent of designs and a superintendent of manufacture, all of whom should preferably be civilians and should give their whole time to the affairs of the Factory, and a Military Advisor without distinct executive duties. The three last-named gentlemen should rank equally with one another on the Board. The Director should be well equipped with previous commercial and scientific, engineering qualifications and experience. It is not considered essential that he should possess any intimate or previous knowledge of aviation. He should be selected for his recognised ability in administration and management.
>
> We believe the organisation we are suggesting would be much assisted by the appointment of a civilian of high standing and suitable qualifications as controller of aircraft supplies who would have his headquarters in London and have among his duties the direct communication with contractors and the Royal Aircraft Factory.
>
> As we believe that the capacity of the Factory could be greatly augmented without increase to the present number of employees, we suggest that this should be arrived at in the shape of additional current manufacture of aeroplanes and engines, without impairment, and indeed with increased efficiency of the experimental functions of the Royal Aircraft Factory as now existing.
>
> We think it would be better that direct contact with contractors, including the issue to them of drawings, should be made through a third party, e.g. the controller of aircraft supplies, and not by the Royal Aircraft Factory.

While waiting for the report to be made public, Billing continued to wage his war against what he saw as the mismanagement of the nation's flying services. On 2 May he asked the House whether his allegations as to the inefficiency of the B.E.2c had yet halted the issuing of the type to the squadrons in France, only to be told that they had not. However, only five days later the Army Council appeared to succumb to the constant pressure,

and announced their intention to establish another commission, this time 'to enquire into the administration and command of the Royal Flying Corps with particular reference to the charges made in Parliament and elsewhere against the officials and officers responsible for that administration and command and to make any recommendation in relation thereto'. A few days later the House was informed that the commission would consist of six men (four of whom were lawyers), under the chairmanship of a high court judge, Mr Justice Bailhache.

Among the witnesses examined by the commission were Gen Sir David Henderson, Director General of Military Aeronautics, Mervyn O'Gorman, and Dr Glazebrook, Director of the National Physical Laboratory, all of whom praised the B.E.2c and supported the War Office's decision to adopt it. Mr Joynson-Hicks MP and C G Grey naturally took the opposing view.

These deliberations over the decision, taken some years previously, to adopt the B.E.2c were all somewhat academic, as the Department of Military Aeronautics at the War Office had long regarded it as outdated and had started seeking a replacement.

The Factory's own new two-seater, the R.E.8, employed a wing structure very similar to that of the later B.E.2e but had a totally new fuselage and was powered by the Factory's 140hp R.A.F.4a. The pilot occupied the front cockpit and the observer the rear, where he was provided with a Lewis machine gun with which to ward off attackers. It was originally intended that deflector plates should be fitted to the propeller to allow a forward-firing machine gun to be fitted, but the completed machines were eventually equipped with one of the several interrupter gears finally developed by the Allies during that summer, thereby rendering the deflectors unnecessary.

The first prototype flew on 17 June, followed by a second on 5 July and, although there were some small adverse criticisms, the new machines were

A production R.E.8, built by the Coventry Ordnance Works, with the deeper sump cowling introduced for later machines.

generally considered to possess splendid flying qualities, to be easily manoeuvred, and to have an impressive speed range (47 to 103mph). The R.E.8 was consequently ordered into quantity production from a number of manufacturers, as were several rival designs from private firms, including the Armstrong Whitworth F.K.8 and the Bristol F.2b.

In view of the development of these aeroplanes, all of which were superior to the now obsolete B.E.2c, it is perhaps remarkable that contracts to build the earlier design were allowed to be fulfilled, rather than being cancelled in favour of the new machines. As it was, one contractor did not complete delivery of a batch of totally obsolete B.E.2bs until early 1917.

On 19 July the report of the Burbidge Committee, to which proposals from the Air Board had been added (the latter had only been established on 11 May at the suggestion of Lord Curzon, who became its chairman, with the intention that it should co-ordinate management of Britain's flying services), was finally published as parliamentary paper No Cd 8191.

This document defined the rôle of the Royal Aircraft Factory as being:

1 To make experimental construction of all sorts—aeroplanes, engines, kites, balloons, armaments, bombs, instruments and sundries—on the full scale, and verifying, criticising, and making suggestions to guide the model research work of the National Physical Laboratory and Advisory Committee.

2 To get out from these experiments designs suitable for reproduction by the RAF and private firms.

3 To set a standard of workmanship, design, performance of aeroplanes, kites, balloons etc., as well as armaments, bombs, bomb-sights, gun mountings, camera fittings, wireless apparatus, protective dopes and pigments etc.

4 To make aeroplane designs conform to the War Office requirements by incorporating in the designs the armament and equipment for military purposes.

5 To manufacture spares of all kinds.

6 To assist the trade and industry of aircraft making:
(a) by introducing standardisation of parts and sub-parts.
(b) by manufacturing such pieces as are for some reason or another holding up or delaying private makers.
(c) by teaching their employees how to make parts which are novel to them: propellers, special castings, special tools, taps etc., Raf wires, dope, varnish, pigments, instruments, compasses etc.
(d) by providing them with full working drawings.

7 To assist in keeping the Government free from the pressure of monopoly prices by working out the costs of aeroplanes and sundries; and in the event of a monopoly being formed, breaking the monopoly by manufacturing against the monopolists and finding designs which meet the same technical results which can be put up to Public Tender.

8 To effect repairs (repairs generally cannot be quoted for by private firms owing to the complexity of quoting, involving dismemberment of a broken aircraft or engine).

9 Consulting engineering work: To assist the War Office by producing drawings and blueprints in enormous quantities, preparing catalogues, index numbers for ordering spares, instructions for using appliances.

10 To supervise the technical routine of contracts for new RAF engines.

11 To conduct metallurgical and chemical experiments on new substances and to test specimens of all sorts.

12 To report on inventions and devices.

13 Incidental to the urgent expansion of work, it has been necessary to design engine testing plant, chemical production plant, and to effect unusually large amounts of upkeep and other work in adapting buildings—design of aeroplane shops of unprecedented size, etc.

Finally, the Air Board chose to overthrow the suggestions of the Burbidge Committee, and stated:

> They do not agree that the Factory should be placed under a Board of Management. Such an arrangement, however suitable for a private factory, would be ill-adapted to the exigencies of military organisations. The Factory should be under the direction of a single Superintendent possessing special qualifications of business experience and administrative capacity. In this connection Colonel O'Gorman has rendered eminent public service in design and construction of aircraft, but these abilities can be best employed in the future in the capacity of consulting engineer to the Director-General of Military Aeronautics at the War Office.

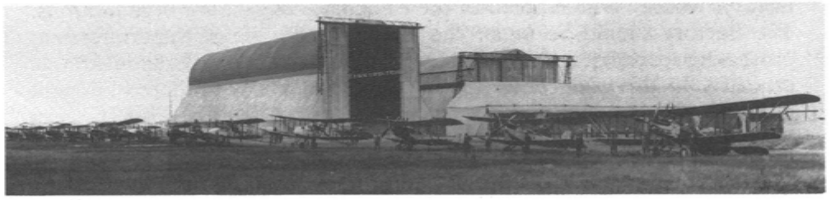
Thus O'Gorman, judged to be the victim of his own success, was in effect to be made a scapegoat and, with his original seven-year contract almost at an end, was to be given a sideways promotion. He bitterly resented what he saw as unjust treatment, but nevertheless prudently accepted the post offered, which was in reality merely a sinecure, and lived in virtual retirement until his death in 1948.

The Air Board's comments continued:

> Under the proposed new Superintendent there should be a Head of Design and a Head of Production. The Air Board do not share the view that a military advisor should be attached to the Factory, as this could be better discharged by the Director of Aircraft Equipment at the War Office.
>
> The Board agree that direct communication between the Factory and contractors should be a minimum, and do not think it necessary to create a post of Controller of Aircraft Supplies as intermediary between Factory and contractors, as this can be adequately discharged by the Department of Military Aeronautics, as at present constituted.
>
> The proposal of the Committee that the capacity of the Factory should be directed to an increase of the current manufacture of aeroplanes and engines, raises a difficult question. There is no doubt that from a financial point of view such extension is desirable. The larger the proportion of production to experiment, the more creditable will the balance sheet of the Factory appear. On the other hand, not only does the present

production of the Factory, limited as it is, arouse some measure of suspicion in the minds of private manufacturers, but any such extension in the case of engines is, under existing conditions, impracticable. An increased production of engines could only be obtained if new shops were built. But there is no room for their construction; and even if there were, no output could be obtained in less than ten months. The object to be aimed at, in the view of the Air Board, is an increase in the output of aeroplanes by an improved organisation of the existing staff. No reduction should be made in the amount of experiments conducted at the Factory. On the contrary, this is the aspect of their work which it is desirable to emphasise by every possible means.

So, by recommendation of the Committee of Inquiry and with the support of the Air Board, the Royal Aircraft Factory was instructed to undertake increased levels of aeroplane production, the exact way in which this was to be achieved being left to the new Superintendent to decide. This was hardly an outcome calculated to appease the Factory's critics.



The occasion which prompted this impressive line-up of Factory designs is unfortunately not recorded, nor is the purpose of the marquee behind them, but the types present suggest a date of mid-1916. Left to right, the aircraft are: B.E.2c, B.E.2c, B.E.2b. B.E.12, Hispano-Suiza-powered B.E.2c, F.E.8, S.E.4a, F.E.2c, F.E.2b, R.E.8, R.E.8, and R.E.7.
(Imperial War Museum)

A further phase of expansion which had begun in April 1916, before publication of the Inquiry's report, was utilised both to increase workshop space and, later, to equip the Factory better for its true rôle as a research facility. Two windtunnels, each seven feet square, were built, replacing the simple tunnel built ten years previously and which had long since fallen into disuse, being hopelessly obsolete. With these two new windtunnels the Factory ceased to be reliant upon the facilities of the National Physical Laboratory. The new Farnborough tunnels did, however, have one slight defect which was not realised until many years later. The airflow through them was not fully expanded, and had a slight tendency to cling to one side, although this did not seriously affect test results at the speeds used during this period.

With the assistance of prisoner-of-war labour a central power station was built from which steam was distributed throughout the works, the pipes running in underground ducts constructed of concrete which, in order to conserve steel stocks for use in ways more directly connected with the

waging of war, was reinforced only with chicken wire, an innovation which proved remarkably effective.

The new buildings were erected to the north of the original site, away from the aerodrome, the perimeter fence being extended to enclose them and a new entrance gate being constructed on the Factory's northern boundary. This gate was for the admittance of goods and for the clocking-in of hourly-paid workers, each of whom had a small badge with their works number on it for identification. Salaried staff and officers continued to use the south gate, but carried no badges as they expected to be recognised by the gateman on duty there.

The new North Gate photographed shortly after the end of the war. The building to the left is the Men's Mess or canteen.
(via Paul S Leaman)

The 1915/16 report of the Advisory Committee for Aeronautics, published that August, was necessarily far briefer than in previous years, as much of the work of the Royal Aircraft Factory, and of the National Physical Laboratory, was considered to be secret. Among the work which it felt could be recorded (although not fully described) without being of assistance to the enemy was:

- **a** Full-scale research by experiment and observation of aeroplanes in flight as well as windtunnel tests on scale models.
- **b** Aerodynamic tests on streamline wires, demonstrating that the resistance of 'Raf-wires', which were a simple, symmetrical ellipse, was so little greater than wires of true streamline form that their universal adoption was recommended.
- **c** The design and development of aircraft instruments and of bomb sights.
- **d** The design and development of wireless sets.
- **e** The design and development of variable-pitch airscrews and their testing by means of the newly-constructed 70mph whirling arm.
- **f** Experiments with fabrics and dopes.
- **g** Testing of all metals used in aircraft construction.
- **h** The design and construction of new experimental aircraft based upon new knowledge and devices.
- **i** Special tests on fuels, oils, magnetos and spark plugs.

It was also reported that a lower factor of safety than the six originally required could now be allowed because of the greater precision which was

now possible with improved methods of calculating loads, stresses and material strengths. Information regarding these calculations was to be made freely available to private contractors.

Much of the observation of aeroplanes in flight referred to was conducted from the top of Pyestock Tower, the chimney of an unused horse incinerator which was located near Eelmore Flash, a body of water at the south-western edge of Laffan's Plain. Many 'air-to-air' photographs were taken from this vantage point, which, although it was provided with internal steps, was described as being 'a long climb with a heavy plate camera'.

Work not detailed in the Advisory Committee's report included the mathematical investigation, by two stressmen, Barling and Webb, into the design of tapered struts, which saved both weight and drag when compared with parallel-sided struts of equal strength. They discovered that a straight tapered strut having its central portion parallel-sided and the ends of half the linear dimensions of the mid cross-section gave a saving in weight of 12½ per cent, compared with 15 per cent for the perfect shape, but were far simpler to design and to manufacture.

An apparatus designed and operated by Geoffrey Taylor was able to measure the air pressure over the surface of a wing in flight. Readings were taken at twenty different points on the chord of a B.E.2c wing over a speed range of fifty to ninety-seven miles per hour, thereby verifying, by full-scale tests, the figures for lift and drag obtained by windtunnel experiments.

Research was conducted by A H Gibson and S D Heron to establish the optimum thickness and spacing for the fins on the cylinder of an air-cooled engine. J E Ellor began investigations into the advantages of various methods of engine supercharging, and A A Griffith established the degree to which propeller shafts would be weakened by the cutting of key-ways and splines. This investigation into what was, in fact, metal fatigue, led to the discovery of the 'Griffith Crack' phenomenon, and he became the first man to be made a Fellow of the Royal Society for research carried out at Farnborough.

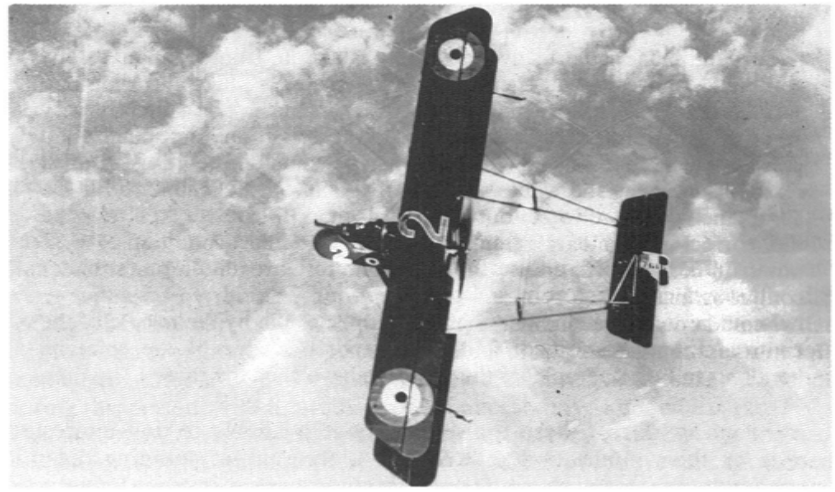
While this work was perhaps of no immediate effect, it was important in preparing the way for future developments. It was undoubtedly just the sort of thing which F W Lanchester had in mind when he wrote in praise of, '. . . the conspicuous ability shown by the staff of the Royal Aircraft Factory in making practical use and application of the latest and best information at their disposal, and in their own full-scale experimental work and study of the many practical problems outside the range of purely scientific research'.*

At this time the phenomenon of the 'spin', in which an aeroplane spirals down in a fully stalled condition, was still far from being fully understood. Incidents of pilots successfully recovering from a spin—without always being aware of how they had done it—went back at least to 'Parke's Dive' of August 1912, when Lt Parke managed to land safely after his 50hp Avro entered a spin at about five hundred feet. Many flying instructors were service pilots on six months' 'rest' from front-line flying, and passed on to

* FW Lanchester, *Aircraft in Warfare*, (Constable, London 1916).

their pupils a repeat of their own instruction, which often dated back to simpler days. Many pilots were still apprehensive of spinning, and few would do so voluntarily. For an aeroplane to be thought 'prone to spinning' was almost the worst condemnation that service pilots could make. Following a number of incidents, such allegations began to be made in respect of the F.E.8, now entering service in France.

Therefore, on 23 August, in a praiseworthy effort to end these rumours before they gained too much ground, Frank Goodden made a number of deliberate spins in an F.E.8, recovering successfully on every occasion. He then wrote the following report:



A 41 Squadron F.E.8, 7616, photographed in flight. The streamers denote that it is piloted by a flight leader.
(JM Bruce/GS Leslie)

> At a height of 3,500 feet I put on gradually all right rudder, and at the same time gradually pulled the control stick over to the left. In this way the aeroplane was turned to the right without any bank. When I had turned the machine in this manner for about 180 degrees the speed had dropped, due to the turn and the resistance of the fully-over rudder, and flaps [ailerons], to nearly stalling speed. The nose of the aeroplane then went gradually down, due to the loss of speed. I next pulled back the control stick and this increased the turning speed, and when I had completed 300 degrees turn the spinning suddenly started.
>
> I kept the control stick in the position described above, and the spinning continued and gradually got steeper. The whole aeroplane was then turning about a point mid-way between the right-hand wing tip and the body.
>
> In this way I tried three spinning tests to the left and three to the right, and whereas spinning starts after about 300 degrees on the right-hand turn with control as described above, spinning to the left does not take place

until a turn and a half have been completed.

In bumpy and disturbed air a turn attempted with the controls set in the manner described would undoubtedly start the aeroplane spinning much earlier in the turn.

The following was the procedure adopted to get the aeroplane out of the spin:

1. Switch off motor.
2. Control stick put central and pushed forward.
3. Rudder put in centre.

This resulted in a nose dive, from which the aeroplane, having once got up speed, can easily be pulled out with the control stick pulled back slightly.

If the aeroplane is dived to bring it vertically downwards, spinning cannot continue, provided all the controls are central.

This aeroplane is perfectly stable, and is as safe from spinning as any aeroplane I have flown. There are large elevator, rudder and wing flap surfaces, and the controllability of the aeroplane is consequently very great. This controllability, which is so desirable in any aeroplane, and particularly in a fighting machine of this type, should it be misused, must result in upsetting the whole stability of the aeroplane. Similarly, if the aeroplane is allowed to get out of control, then, if care is taken to make the correct movements required by the particular conditions, these powerful controls will enable the aeroplane to be readily brought under control again.

I could only succeed in making the aeroplane spin by the misuse of the controls I have described, and from reports I have of the spinning accidents to F.E.8 aeroplanes this seems to have been the cause.

Although details of these trials were made available to any interested parties by their publication in R&M 168, the fear of spinning did not immediately disappear. Nor did the method of recovery become universally known, and many more preventable accidents occurred. But at least service pilots accepted the F.E.8 as sound, realising that the deficiency in spin recovery probably lay in their own piloting skills.

Change and decay

On 21 September 1916 Henry Fowler succeeded Mervyn O'Gorman as Factory Superintendent. Those responsible for his appointment had clearly taken note of the Burbidge Committee's suggestion that the appointee needed sound management skills and an engineering background but need not necessarily have any detailed knowledge of aeronautics, for Fowler's previous post had been as chief mechanical engineer for the Midland Railway.

It is perhaps coincidental that at this time the standard-gauge railway, which had been built many years earlier and was used principally for moving hydrogen cylinders within the compound, was extended, through gates in the perimeter fence, to connect with the LWSR main line at Farnborough Station. The construction work was carried out by prisoners of war, under the supervision of men of the Royal Engineers.

A number of the Factory staff, especially those closer to him, appear to have felt some resentment at O'Gorman's departure, or at the circumstances thereof, for it was felt that he had been treated unfairly, and few were appeased by the new appointment. The morale at Farnborough, the feeling of being part of a family was, at least for the moment, somewhat blighted, and without their accustomed mentor some members of staff seemed to suffer a loss of direction. It is therefore hardly surprising that during this period, with its atmosphere of uncertainty, some of the Factory's least successful designs were brought to fruition. However, despite the loss of some of its more gifted staff, who went in search of the greater rewards to be found in private industry, the Royal Aircraft Factory was still far from being a spent force in aeroplane design.

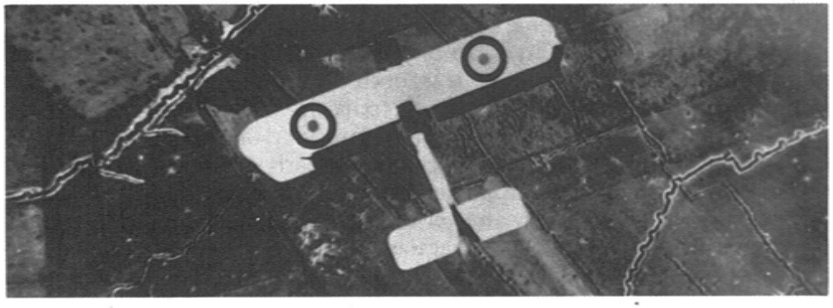
An attempt by the RFC's Experimental Works at Feltham to build a radio controlled flying bomb was begun late in 1916 under the direction of the unit's Commanding Officer, Capt A M Low. Low's undoubted skill with wireless did not extend to aeroplane design, and the Factory was requested to produce a suitable machine. H P Folland appears to have been responsible for the resulting small shoulder-wing monoplane, which was given the name 'Aerial Target' to disguise its true purpose. Six examples were built at Farnborough and transported to Feltham for the wireless equipment to be installed. Initial flight trials were not successful owing to difficulties in establishing correct trim before take-off, and the tests were abandoned. The project was resurrected in the early 1920s, the radio system being perfected in piloted aeroplanes before being installed in the airframe designed for it. These post-war 'Aerial Targets' were almost certainly the last full-sized aeroplanes ever built at Farnborough.

The report of the Bailhache Committee's enquiry into the administration of the Royal Flying Corps, which had been commissioned in May, was finally published in December 1916. It prompted *Flight* magazine to comment:

It was said that the feeling of the trade against the Royal Aircraft Factory was bitter, but as to this the Committee had no evidence from trade witnesses. Some of the witnesses went so far as to say that the Factory was a competitive manufacturer with private firms. This was so contrary to the facts that the Committee dismissed the suggestion as frivolous. The Factory had built no engine except experimentally, and has only constructed for use 77 aeroplanes, of which 50 were to assist a private maker in fulfilment of an order.'

It has not been possible to ascertain the source of these figures, but it is almost certain that they are accurate, assuming that it is fair to exclude those machines, such as the B.E.9, which were rebuilt from existing airframes. Even if such machines are included the total approaches 130, including fifty F.E.2ds built to assist the unnamed private maker, which is still a very small number for an establishment of the magnitude of the Royal Aircraft Factory.

In fact the Bailhache Committee had experienced great difficulty in obtaining witnesses, either from the junior ranks of the RFC or from the trade, only a handful of the fifty-four witnesses actually examined representing the opinions of aircraft manufacturers. The Committee's report dealt at some length with the difficulties experienced in developing a totally new armed force and in foreseeing the types and quantities of equipment which would eventually be needed for its use. It recognised that new airframes had to be designed around existing power units, not *vice versa*, and that Britain had been, and was still, confined by the limits of her indigenous engine production, augmented by those engines of foreign origin which she was able to purchase. The report did express the opinion that the RFC may have placed too great a reliance upon the Royal Aircraft Factory, but refuted criticism that the Factory had acted both as competitor and judge. However, it accepted that it was almost inevitable that such a view would arise, because those officers and inspectors who were responsible for advising Gen Henderson, the Director General of Military Aeronautics, which aeroplanes should be selected for production, belonged to the same department of the War Office as the Factory itself.



An unidentified B.E.2c, one of many on reconnaissance duties over the trenches of the Western Front.

The report suggested that the Royal Aircraft Factory was best judged by its principal achievement, the B.E.2c with the 90hp R.A.F.1a engine; it was strong, aerodynamically sound, and its drawings were so detailed that many firms who had never previously built aeroplanes were able to do so. One of the few trade witnesses to be heard, Algernon Berriman, chief engineer at the Daimler Company, was quoted as saying, 'The R.A.F. engine and the B.E.2c aeroplane have their defects, but they form a combination that has been instrumental in enabling the Royal Flying Corps to perform invaluable service in France'.

It was also pointed out that three of the enemy airships whose bombing raids on England had brought the war to the civilian population had been brought down by B.E.2cs, whose stability made them particularly suitable for flying at night.

In conclusion, the Committee answered the charges which had brought about its own formation with the words: 'No-one could complain if Mr Pemberton Billing had asked that these cases should be enquired into to ascertain whether the deaths of these men could have been prevented. But based upon these incidents a charge of criminal negligence, or murder is an abuse of language and entirely unjustified.'

Thus, while no blame was directly attached to the Factory or to its staff by the Bailhache Committee's inquiry into the management of the Royal Flying Corps, little or nothing had been said or done to alleviate its feelings of dissatisfaction, even of persecution. Nor was there any comfort in the Committee's recommendations, which included the suggestion that the selection and supply of equipment for the RFC should be separated from its executive command and that the Royal Aircraft Factory should not become a manufacturing establishment.

This was, of course, in complete contrast to the conclusion of the Burbidge Committee, which had inquired into the management of the Factory itself. It also came too late, because the industry was already saturated with orders, and the Factory had begun volume production of some of its own designs in an attempt to make up some of the shortfalls.

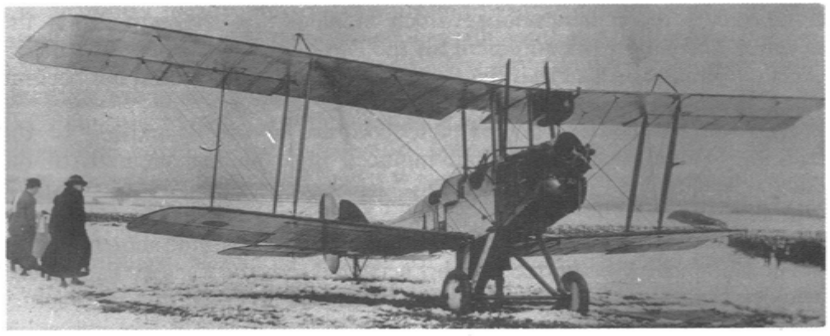
The Bailhache Committee's report accepted that the Factory had indeed produced some unsatisfactory designs, but it also accepted that the Factory existed primarily to make experiments, and agreed that it was inevitable that some experiments must fail. Although there was some consolation in this official recognition that not every idea could be right or every design be perfect, it was fortunate for the progress of the war in the air that the Factory design currently reaching fruition eventually proved almost perfect, even though it came close to failure at first.

The first prototype S.E.5, A4561, had been completed in November 1916. It was test flown by Frank Goodden, who reported his delight in the performance of the scout he had helped to create. Two more examples, A4562 and A4563, were completed before the end of the year, and after Christmas Goodden took A4562 to France for service trials, returning to Farnborough on 4 January 1917 with a list of minor modifications requested by front-line pilots. These were completed by 26 January, when Goodden took A4562 up for a brief flight. Two days later he took it up again but, after

about ten minutes in the air, one of the wings was seen to break away at an altitude estimated at about 1,000ft. The machine crashed, Goodden being killed instantly. He was 26, and, as a Royal Aircraft Factory test pilot since 1914, had made the initial flights of at least six entirely new designs. He was buried in Aldershot Military Cemetery, joining Cody and Busk, both of whom had met their deaths in crashes on Laffan's Plain.

The Aeroplane for 31 January carried an editorial in which Goodden was pilloried, and his achievements belittled, in an attack upon War Office policy and upon the Royal Aircraft Factory which was uncharacteristically biased, even for C G Grey.

By now accustomed to abuse, even of this vicious kind, the Factory took little notice. An internal enquiry, set up to ascertain the cause of the disaster, eventually reached the conclusion that the propeller had broken, resulting in enormous out-of-balance forces which caused the wings to flex, shed the interplane struts, and collapse. However, an independent investigation by the Military Aeronautics Department concluded that a design deficiency had allowed the wing to break up internally. An examination of the first prototype, A4561, revealed that this suspected weakness was indeed present, and the structure was redesigned to prevent a recurrence of the failure. This modification was incorporated in all S.E.5s. The type had by now been put into mass production at the Factory, entering service the following June as the RFC's first two-gun fighter.



This unidentified B.E.2e (or g), forced down by a blizzard near Wragby in Lincolnshire, clearly shows the long upper-wing extensions which distinguished the type and which gave rise to initial concern regarding their strength.
(via PHT Green)

Investigations were also undertaken by the Factory and by the Military Aeronautics Department into the causes of the collapse, in several separate incidents, of the B.E.2e's upper wing extensions. These occurrences had led to rumours in RFC squadrons that the newest B.E. could flap its wings. Eventually it was agreed by both groups that the collapse actually occurred not upwards, as had been supposed, but when the wing was subjected to excessive downloads. This conclusion resulted in revised design requirements for resistance to compression forces in all future machines.

The Factory's continued bad press and its ever more tarnished image did nothing to prevent the loss of key personnel. Tempted, not only by enhancing salaries, but by the opportunity to continue with the work they enjoyed most—the design of aeroplanes—they continued to leave for posts in industry, free from constant criticism.

At the end of January F M Green, who had been O'Gorman's first recruit, left to join the Siddeley Deasy Motor Car Company as chief engineer, effectively the same position he had held at Farnborough. With him went S D Heron and, if not the actual plans of the R.A.F.8 engine, then at least a detailed recollection of its layout, to assist him in the design of what would eventually become the Armstrong Siddeley Jaguar. Another member of the Factory staff to move to the Siddeley Deasy Company was J Lloyd, who had been involved in the design of the R.E.8. He designed a revised version of the machine for his new employer, designated R.T.1.

Henry Folland, designer of the S.E.5, moved to Nieuport and General Aircraft. He was soon joined by H Preston, from the Farnborough drawing office, and L Hall, who had been manager of the Factory's Mechanical Engineering Department.

Among the other designers who left Farnborough were John Kenworthy, who became chief designer at Austin Motors, Harold Bolas, who took a similar post at Parnall Aircraft, and F Bennell, who joined Boulton and Paul. Sam Hiscocks was reunited with Geoffrey de Havilland at the Aircraft Manufacturing Company, where he became works manager, and S J Waters joined the staff of the American company, Douglas.

The staff of Farnborough's engine department were dispersed throughout private industry, with J E Ellor continuing his work on engine supercharging as an employee of Rolls-Royce, P L Teed moving to Vickers, and J S Irving taking up the position of chief engineer at Sunbeam. G S Wilkinson moved to Napier, which was then mass-producing the R.A.F.3a, only to find that it was attracting the adverse criticism which now seemed inevitable for any Royal Aircraft Factory design.

S Heckstall-Smith, the assistant Superintendent, and William Farren also left, although the latter returned to Farnborough many years later to become Director of the RAE during World War Two.

At the beginning of April Noel Pemberton Billing, who was obviously not entirely satisfied with the outcome of the inquiries he had been instrumental in bringing into being, or with the rate at which obsolete aeroplanes were being replaced, was again on his feet, advising Parliament of the inadequacies of Britain's air services. He alleged that, at the present rate of wastage, the entire British front-line strength would be wiped out within a few months. Although his claims were based on official casualty figures, he ignored any input by way of replacements, a dramatic trick which was intended to highlight the situation and give him further reason to decry the continued use of B.E.2 variants.

In fact this month, tragically remembered as 'Bloody April' was to be the worst in the RFC's short history, and was, unfortunately, to prove even PB's doctored figures to be conservative. While the Allies had managed to counter the threat of Germany's first generation of fighter aircraft, the

Fokker monoplanes of 1915/16, they were unable, immediately, to match the Albatros biplane fighter which had arrived in service in sufficient numbers to turn the tide of aerial supremacy easily in Germany's favour. Although the Allied scouts were suddenly outclassed, they managed to hold their own, largely by massing in strength and endeavouring to avoid single combat, but the new enemy fighters created havoc among the slow, poorly armed two-seaters as they diligently went about their duties in preparation for the spring offensives.

A standard production S.E.5a with a geared 200hp Hispano-Suiza engine. *(via RB Pope)*

Towards the end of the month the arrival in service of the first squadron of S.E.5s, now in volume production at the Royal Aircraft Factory, marked the first small step towards redressing the balance of power. Their steadily increasing numbers, together with those of the Sopwith Camel, which entered service some weeks later, slowly allowed the Allies to gain the upper hand for the first time since the war began. But there was never again to be a place in the skies for a defenceless aeroplane, and the B.E.2s were finally phased out in favour of a number of better-armed machines, the most numerous of which was the Royal Aircraft Factory R.E.8.

The Royal Aircraft Factory's interest in aeroplane handling and stability remained undiminished, and much of the investigative work carried out by its staff concerned this subject. One of the many discoveries made was that wingtip planforms in which the leading edge was longer than the trailing edge, such as those of the B.E.2c or Sopwith Pup, resulted in lighter and more effective aileron control than those in which the reverse applied. Unfortunately the latter form was the more common. Aileron control, which in the S.E.5 was virtually non-existent at airspeeds below seventy miles an hour, was much improved by reducing the outward rake of the wingtips, and this new planform was adopted for the revised S.E.5a, which was built in large numbers by private constructors as well as by the Factory.

To determine the loads placed upon an aeroplane both by turbulence and by voluntary manoeuvres, two Factory scientists, F C Searle and F A

Lindemann, constructed an accelerometer, which comprised a semi-circle of very fine glass fibre, one inch in diameter, with both ends fixed, whose tip was illuminated so that its motion could be recorded on film, the whole assembly being air damped by enclosing it within a box. With the aid of this device it was established that the aerodynamic loads upon a B.E.2c were as follows:-

Loop at 95mph	=	3.2*g*
Rolling at maximum rate	=	2.8*g*
Stall	=	2.8*g*
Bumps and gusts	=	1.5*g*

During a mock dogfight between an S.E.5a flown by Roderic Hill and an R.E.8 flown by Capt Noakes it was found, using instruments of the same type, that the acceleration forces caused by the various manoeuvres could reach 4*g*.

As the staff in the Factory's main drawing office slowly brought their design work to a close, the scientists and engineers who occupied the research unit usually referred to as the Small Drawing Office continued their investigations into 'scale effect'. This phenomenon, the relationship between full-size machines in flight and their scale models tested in windtunnels, was appreciated but not entirely understood, and one group was trying to arrive at a mathematical formula by which the difference could be calculated. This necessitated obtaining readings of cockpit instruments at set intervals, gauged by stopwatches, and the accuracy of the results was entirely dependant upon the skill of the observer performing the work. Since this had to be done during a test flight, candidates for any vacancies which occurred were taken up for a trial flight, which included fairly violent aerobatics, to assess their suitability.

Speed was measured between two points along a course which ran from the main office buildings to Pyestock, some two miles away, the chimney at the latter location providing a valuable aiming point and enabling pilots to maintain a straight path.

Lift and drag were assessed during a manoeuvre known as the 'prop-stopped glide', in which, as the name suggests, the possible disturbance of the airflow by the propeller wake was eliminated by climbing to a suitable altitude and gliding down at a constant airspeed without the propeller turning while the readings were taken. The engine was then restarted. A series of glides at differing speeds and angles would provide a lift/drag curve with which the windtunnel results could be compared. These experiments required still air, without wind or turbulence, and were most often conducted very early in the morning.

Another experiment, designed to enable lateral stability to be assessed, consisted of releasing a weight from one wing tip and measuring the roll thus caused by means of a cine-camera filming the horizon. It was soon realised that dropping a solid weight could cause serious damage to people or property on the ground, and attempts were made to use an equivalent weight of loose sand, released from a container. This proved unsuccessful,

as the release was neither instantaneous nor consistent, and the use of a solid weight was reinstated, the experiment now taking place over the sea, which added considerably to the flying time required for each experiment.

Pilots of this period frequently avoided flying in cloud because they lacked any blind-flying instruments and it was possible to become disorientated and lose control. Holding a course proved equally difficult, as compasses would misbehave, sometimes even spinning completely, a phenomenon which pilots believed to be caused by some kind of magnetic influence within the cloud, and which many scientists had considered to be the result of pilots turning without realising it. The solution was found by Dr S Keith-Lucas, a Cambridge physiologist who, like many others, had been called up to work at Farnborough and who went up, as a passenger, to observe the reaction of a compass while the pilot carried out a variety of manoeuvres. He discovered that it behaved, in clear air, exactly as pilots said it did in cloud, and that sometimes it pointed almost to the south, thereby establishing that the problem was with the instrument, not with its environment.

Keith-Lucas then studied the problem mathematically. He discovered that, while turning from a northerly heading, all compasses turn in the same direction as the aeroplane, but at a faster rate, thus giving the impression of a turn in the opposite direction. When turning from a southerly heading all compasses turn in the opposite direction to the aeroplane, and therefore indicate the turn correctly.

The immediate result was that pilots could now descend through cloud in greater safety provided they did so heading south, resuming their chosen course once they were back in clear air.

Eventually a compass was produced which responded more slowly to magnetic forces, so that even when a turn was made while flying north it turned more slowly than the aeroplane, and indicated the direction of the turn correctly. Known as the 'Spherical Compass', because of its shape, it proved a valuable navigational aid.

The aerodynamics of propellers were studied in great detail, using an apparatus capable of measuring the air pressure at various points on their surfaces, similar to that already in use for wings. Much mathematical analysis of the results obtained was undertaken. This work made an important contribution to the investigation then being conducted into the design of variable-pitch propellers. The first practical design was a four-bladed unit which was tested, as now seemed almost inevitable for any Royal Aircraft Factory innovations, on a B.E.2c. The performance of this otherwise unaltered aeroplane showed a slight but definite improvement, despite the new propeller's weight disadvantage of nearly 50lb compared with a normal wooden unit. A similar propeller developed for the S.E.5a demonstrated an equal gain in performance, but was not adopted for use on service machines for a variety of reasons, the main one being the suggestion that its use required a degree of thought which it was felt might distract a pilot in combat.

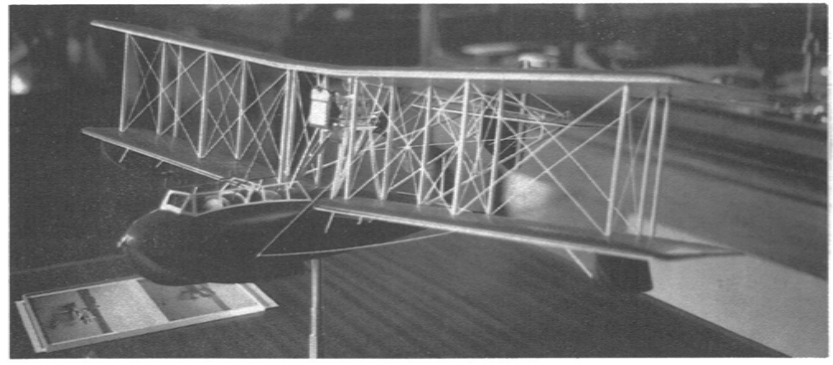
Although there seems to be no direct evidence that the Factory was instructed to discontinue the design of original aeroplanes following the two

Committees of Inquiry, few designs seem to have been initiated thereafter, although those projects which were already in progress were completed. However, the departure of so many gifted designers to private industry inevitably reduced the overall quality of the remaining talent, and although a number of quite practical aeroplanes were designed, none possessed sufficient merit to warrant being placed into production.

The F.E.9, the design of which had been started in the summer of 1916, was a two-seat pusher intended to supersede the F.E.2b, and had a long nacelle suspended in mid-gap. A prototype was completed in April 1917, but, despite the undoubted advantage of a 200hp Hispano-Suiza, it proved disappointing. In any event, it was already out of date and, with the Royal Aircraft Factory's creations now viewed with some slight disfavour by the RFC, it was decided, some time in June, to proceed no further with the F.E.9, especially as there were already far more demands for the Hispano-Suiza engine than could ever be fulfilled.

Although the single-engined pusher, with its inevitable array of tail-booms, struts and wires, was no longer a viable proposition for a conventional combat aeroplane, the layout still held certain advantages for marine aircraft. The hull could be made more seaworthy with nose contours unaffected by the need to locate an engine there, the engine and propeller could be kept clear of spray, and both alighting and mooring were made easier by the uncluttered nose. It was therefore perfectly logical that the pusher format should be adopted for Farnborough's only flying-boat design, the Coastal Experimental or C.E.1.

Design work appears to have started in June 1917 as an urgent response to the massive sinking of British merchant ships by enemy U-boats. With undiminished efficiency by the drawing office and workshops, the first of two prototypes was ready for testing before the end of the year. While the machine proved perfectly satisfactory, entirely fulfilling all of its designers' expectations, the U-boat menace was already being effectively combatted



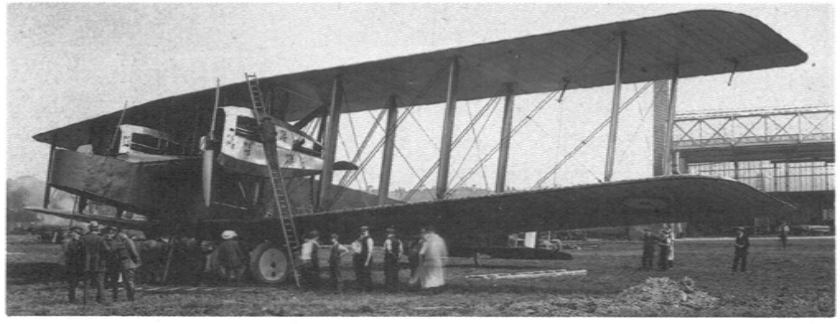
This superb model of the C.E.1, which is housed in the RAE's private museum, clearly shows the forest of booms, struts, and wires which handicapped the performance of such pusher designs.

by other means. As the C.E.1 did not represent a notable advance either in aviation or in marine warfare, no production orders were placed for it.

The pusher layout still offered advantages for night-fighters, where a wide field of fire was more important than performance, and for ground-attack aircraft, where it helped to protect the engine from retaliatory small-arms fire. The former concept was explored in the N.E.1, and the latter in the A.E.3, an armoured two-seat pusher which was completed in March 1918. This machine has the dual distinctions of being the last Royal Aircraft Factory design to be produced and the only Farnborough design to be given an official name, becoming the Ram under the system of nomenclature introduced by the Royal Air Force, which came into being on 1 April 1918. The creation of the new service, by the fusing together of two such diverse organisations as the Royal Flying Corps and Royal Naval Air Service, caused more controversy and required more attention by Whitehall than the reorganisation of the Royal Aircraft Factory had ever done.

With the gradual cessation of aeroplane design the Farnborough-based test pilots, headed by Roderic Hill, found their rôle changing too. They were now required to produce quantitative as well as qualitative reports, and to apply analytical criteria rather than the intuitive approach which had sufficed in earlier days. Their work made possible the publication of such aids to aeroplane designers as R&M 494, which listed data obtained during high-speed dives in a number of aeroplanes, one of which was the S.E.5, now regarded with total confidence following the rectification of the wing defect which had cost Frank Goodden his life.

Now, more than ever before, the Factory was dedicated to providing aerodynamic and structural data for others to use, and to offering every possible assistance to private manufacturers. One example of this co-operation was the Factory's windtunnel tests, and mathematical analysis, of the loss of propeller efficiency which would occur in a tandem (tractor/pusher) engine arrangement such as that proposed for the enormous Handley Page V/1500 bomber then being designed. The Factory's tests

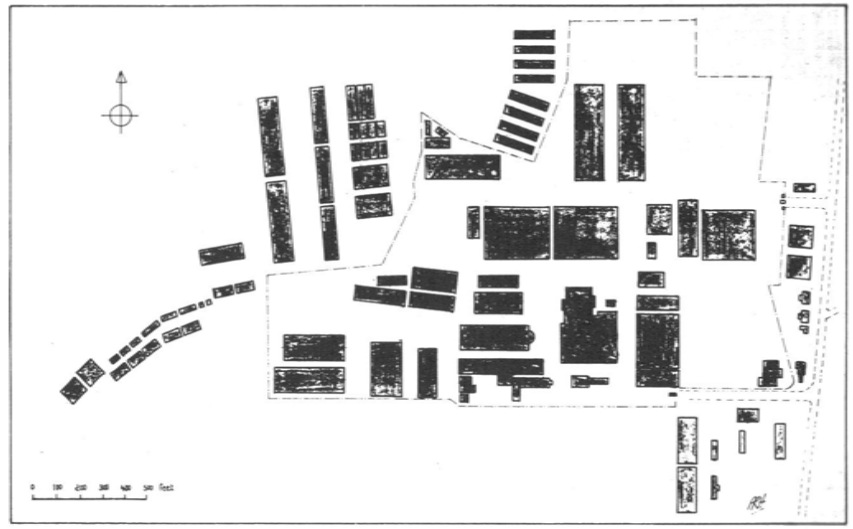


The colossal Handley Page V/1500 bomber. Royal Aircraft Factory research established that the rear propellers in such tandem engine arrangements could never achieve more than ninety per cent of their usual efficiency owing to interference from the slipstream of the tractor propellers.

indicated that the rear, pusher, propeller could never achieve better than ninety per cent of its normal efficiency when working in an airstream already disturbed by the forward, tractor, propeller, even using the optimum combination of size, pitch angle and blade section for each of the two propellers.

Ex-Factory personnel such as Henry Folland, cognizant of the skill and resources that existed at Farnborough, continued to make use of its data and to take advantage of its facilities for the testing of components. Such tests included comparisons of aerofoil sections and of interplane strut designs, including the single struts favoured by Nieuport, Folland's employer, for his proposed new fighter, the design of which was completed too late to see service in the war.

In March 1918 Henry Fowler left the Factory to become Assistant Director of Aircraft Production under Sir William Weir. During his comparatively short time as Superintendent, he had succeeded in changing the Factory's rôle to that recommended by the Burbidge Committee and the Air Board—that of a research and experimental centre.



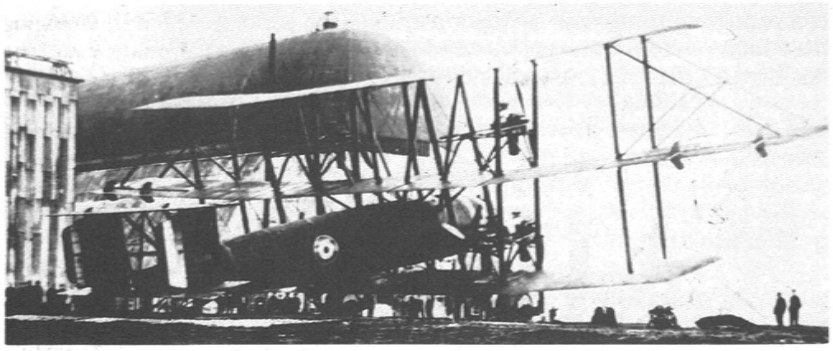
ROYAL AIRCRAFT ESTABLISHMENT, 1918.
The compound has been extended to the north to make space for the new production workshops. The buildings to the north-west house the Southern Aeroplane Repair Depot, and the rows of Pinehurst Cottages can be seen to the north.

Despite recommendations that it was not really desirable, aeroplane manufacture continued at Farnborough right to the end of the war, for the industry, no matter how fast it expanded, could never match the ever-increasing demand for new machines. Thus, during 1918, in addition to a number of prototypes of its own design and about 100 S.E.5as,

Farnborough's workshops built twenty-four Handley Page O/400 bombers and completed two Vickers Vimys, the armistice negating the need for any more.

The new Factory Superintendent, replacing Henry Fowler, was W Sidney Smith, who had previously been employed as a Chief Inspector of Factories.

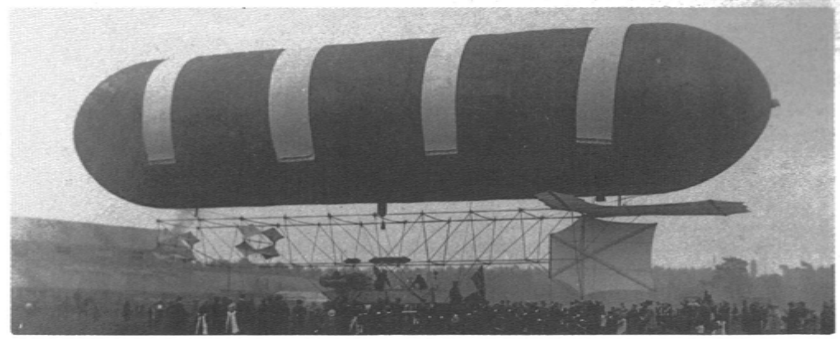
Finally, in June 1918, to avoid a clash of initials with the Royal Air Force, the Factory's name was changed to Royal Aircraft Establishment, thereby finally adopting a suggestion made by Mervyn O'Gorman some two years earlier in the interests of improving the Factory's public image. Thus the transformation was complete, and Farnborough's single decade as a centre for aeroplane design came to an end, leaving behind the renowned research establishment which grew from strength to strength, and continues to the present day.



A view of the western end of what had by then become the RAE, taken from Jersey Brow during 1919. The aeroplane is the unsuccessful Tarrant Tabor, the testing of which was to have been supervised by the RAE staff. Unfortunately the huge machine crashed on its initial take-off attempt, and the project was abandoned.

AIRSHIPS
Nulli Secundus

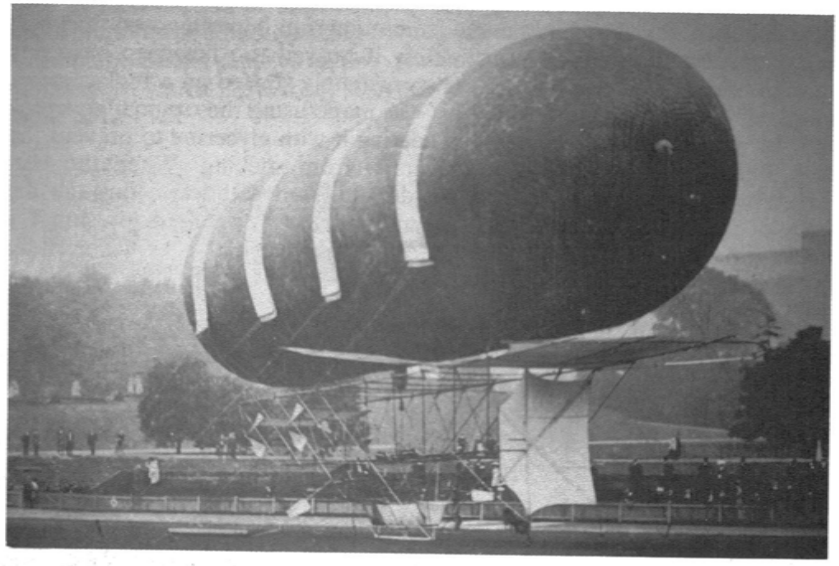
The design of Britain's first military airship was started by Col Templer towards the end of 1902, but little progress was made on its construction until 1904 when, funds finally having been made available, an envelope was fabricated. This was of a very simple shape, being basically a cylinder with hemispherical ends, and was made from numerous superimposed thicknesses of goldbeater's skin. Unfortunately it proved too heavy to have any margin of useful lift, and work was immediately started on a replacement, employing fewer layers of skin. This was made using the original envelope as a mould, inflating it with air and coating it with glycerine to prevent the new skin, which was fabricated over it, from sticking. When the new envelope was complete the first was deflated and withdrawn through the neck of its replacement. Work then appears to have ceased, presumably because the money initially allocated for its completion had been exhausted.



Nulli Secundus about to ascend from Farnborough Common, watched by the usual crowd of spectators.
(via CH Clover)

In 1906 work was resumed by Col Capper, who had succeeded Templer as Factory Superintendent, and the airship was finally completed by the middle of the following year. The boat-shaped car was supported by a framework of two-inch-diameter steel tubing with a wall thickness of 22 gauge and die-cast aluminium joints, which was suspended from the envelope by four bands of silk. The powerplant, which was designed by S F Cody, comprised a 50hp Antoinette engine secured within a framework of ash, driving two propellers by means of proprietary motorcycle drive belts, the belt on the port side being crossed to give contrarotation. The propellers had aluminium blades secured to steel shafts in such a way that their pitch angle could be adjusted. The most effective angle was found by spinning them on a lathe in front of which a heavy nut was suspended on a thread, the angle which blew the nut furthest obviously producing the greatest thrust.

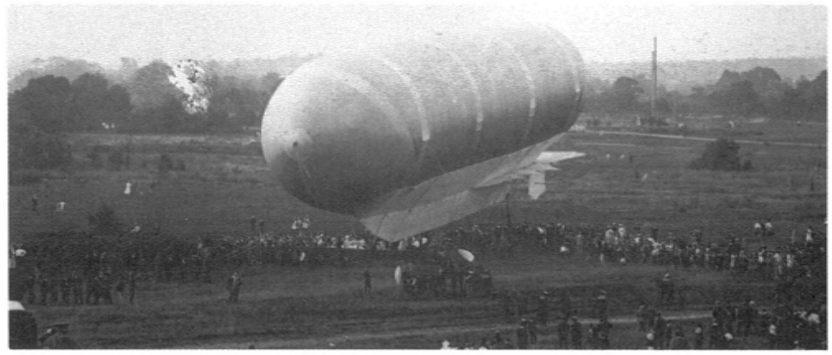
Named *Nulli Secundus*, after one of the King's favourite racehorses, the airship was inflated in August 1907 and made her first flight on 10 September, but proved extremely unstable, pitching almost uncontrollably, and was quickly returned to earth. The solution was found by adding a tailplane and, at the same time, removing the 'wings' which had been fitted amidships to overcome an anticipated instability in roll. This had not occurred, because the car, suspended well below the envelope, provided sufficient pendulum stability in that axis.



Nulli Secundus at the Crystal Palace after its trip around St Paul's Cathedral in October 1907.

On 5 October *Nulli Secundus* made a flight to the capital, circling St Paul's Cathedral, but, unable to make the return journey against the freshening wind, she eventually landed at the Crystal Palace. Five days later, when she was in danger of breaking free of her moorings in a storm, her envelope was slit open and the airship was returned to Farnborough by road.

By the following summer she had been rebuilt as a semi-rigid, with the car much closer to the envelope and its supporting framework covered in fabric to reduce resistance and so improve her clearly marginal top speed. Her first flight in this form, in which she was frequently referred to as *Nulli Secundus II*, was made on 24 July 1908, and was beset by mishaps. During the first take-off attempt the airship demolished a marquee and, on the second attempt, failed to rise fast enough for the ropes to clear the trees, the consequent entanglement resulting in minor damage to the starboard propeller. The airship landed and was quickly repaired, making a satisfactory take-off at her third attempt. She made a flight of about four



Nulli Secundus II, probably on Farnborough Common, where similar crowds were often present during trials as it was, literally, a public common.
(via Paul S Leaman)

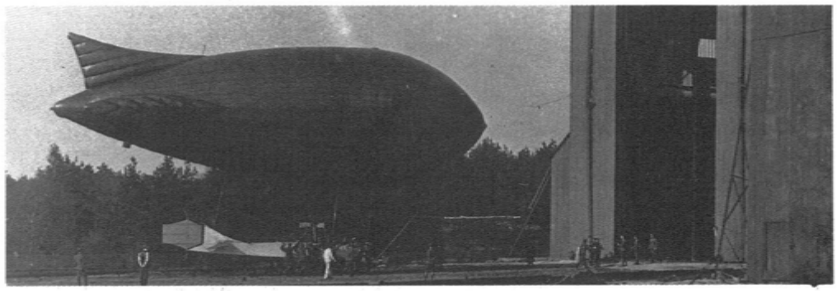
miles on a circular course, so as to keep within reach of her landing ground—a decision which proved prudent when a propeller drive belt began to slip. A hasty landing was made, the airship colliding with a tree in the process. The flight had lasted only eighteen minutes, but it had been long enough to demonstrate that she was seriously unstable. Two more short flights, made after the damage had been repaired, served to confirm that *Nulli Secundus II* was virtually unmanagable, and by the end of August she was deflated, her career at an end.

Powerplant:	40–50hp Antoinette
Dimensions:	length 122ft; diameter 26ft; capacity 55,000 cu ft.
Lift:	800lb
Speed:	16mph (*Nulli Secundus*); 22mph (*Nulli Secundus II*).
Crew	2/3

Baby/Beta

Following the failure of the modified *Nulli Secundus*, it was decided to build a small, purely experimental airship with which to explore handling characteristics. Construction of the new craft, which was intitially designated Dirigible No 3 but was quickly christened *Baby*, began in the autumn of 1908 and was completed by the following spring.

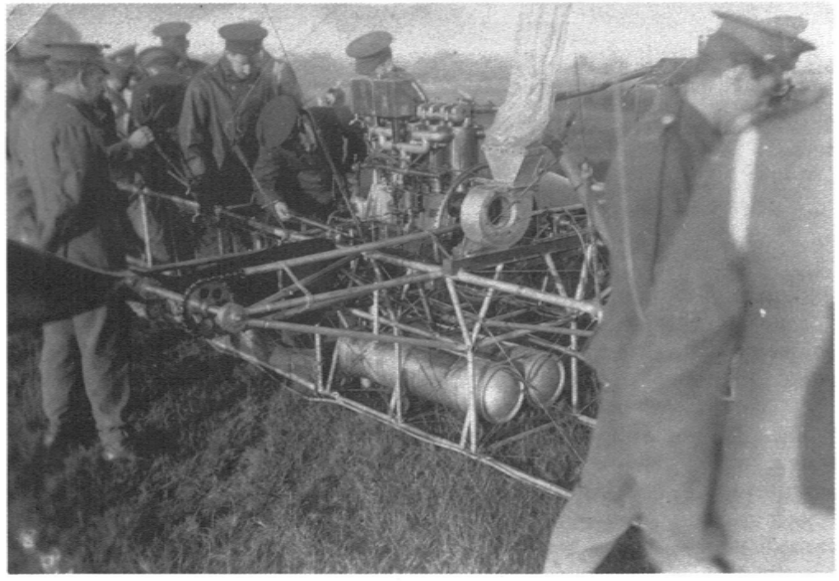
The envelope was of a teardrop shape developed by observing the flow of water over models of various shapes turned from one-inch-diameter ebonite, the tests being conducted by the National Physical Laboratory. It was fabricated from goldbeater's skin treated with a newly developed varnish which, it was hoped, would render the skin waterproof and so prevent any increase in weight by the absorbtion of atmospheric moisture. Initially three stabilising fins, one vertical and two horizontal, formed part of the inflated envelope, but they were found to lack sufficient rigidity at the inflation pressures normally employed and were replaced by fabricated



The airship *Baby* with its original inflated tail surfaces, photographed outside the airship shed.
(via CH Clover)

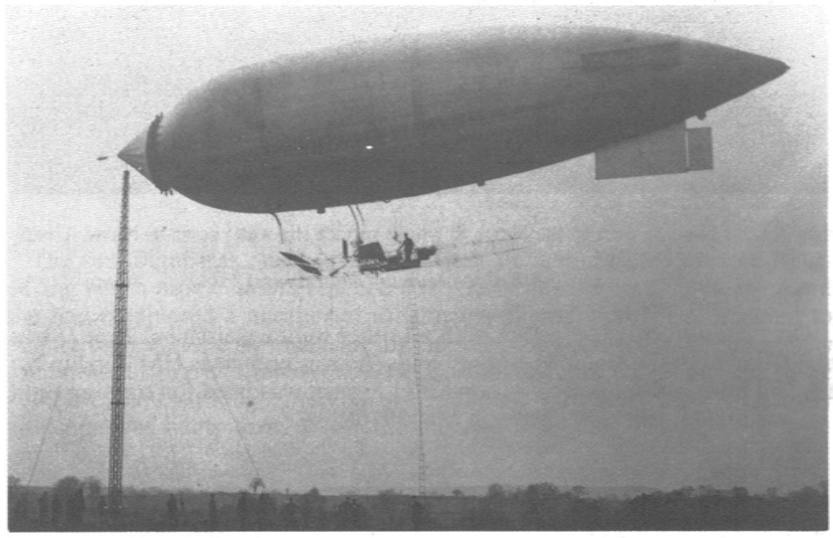
surfaces. Power was originally provided by a pair of 12hp Buchet engines coupled to a single propeller, but these proved excessively troublesome and were quickly replaced by a single REP engine rated at 20hp.

Baby proved to be directionally unstable, due, it was thought, to the shortness of the envelope. On completion of her initial trials it was decided to increase her fineness ratio, and her lift, by lengthening the envelope. This was done by bisecting it at the point of greatest girth and inserting a new section, twenty feet in length. At the same time a 35hp Green engine was



The car of *Beta*, showing its 35hp Green engine and the chain drive to the twin propellers. The small centrifugal fan at the rear of the engines is to inflate the ballonet.
(British Balloon Museum and Library)

substituted for the REP. In this form she was renamed *Beta*, and made her first flight at the end of May 1910. During June she made a flight to London and back, covering a distance in excess of seventy miles in four hours, and was found to have sufficient fuel remaining for a further five hours flight. She took part in the Army manoeuvres that autumn, and in January and February 1911 was equipped with wireless, messages being both sent and received by her at distances of up to thirty miles.

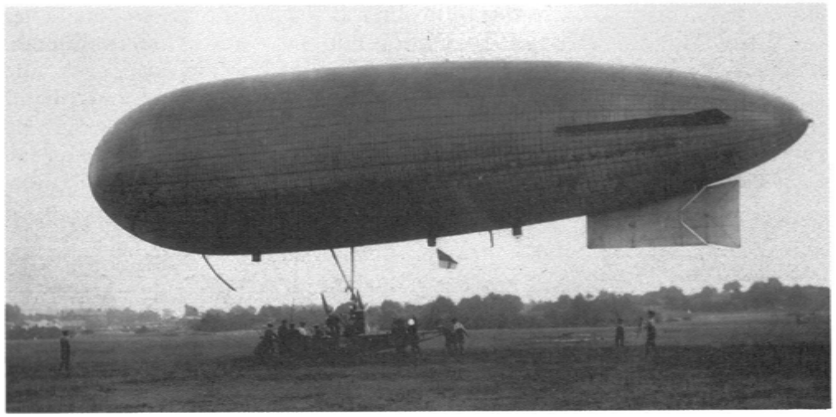


Beta at a mooring mast at Farnborough on 20 February 1912.
(British Balloon Museum and Library)

Beta remained in constant use with the Air Battalion throughout 1911, and early in the following year was used by the Royal Aircraft Factory in the development of airship mooring masts, eventually being moored out in heavy rain and in winds of up to thirty-seven miles per hour. She is described as being 'little worse' for the ordeal, but by March her envelope was reported to be in need of replacement, and it was probably this deterioration which had led to her being chosen for use in the mooring trials.

A replacement envelope of 42,000 cu ft capacity was completed by August 1912, and the enlarged craft, now designated *Beta II*, underwent yet another engine change, this time receiving a 50hp Clerget.

Following participation in the Army manoeuvres of September 1912 she was used to train Naval personnel in airship handling until December, when she was deflated for overhaul. She continued in service throughout 1913, making one flight of over eight hours duration and another in which she reached an altitude of 4,100ft. On 20 June 1913 HRH the Prince of Wales was taken up for a flight, her pilot on this occasion being Capt E M Maitland.



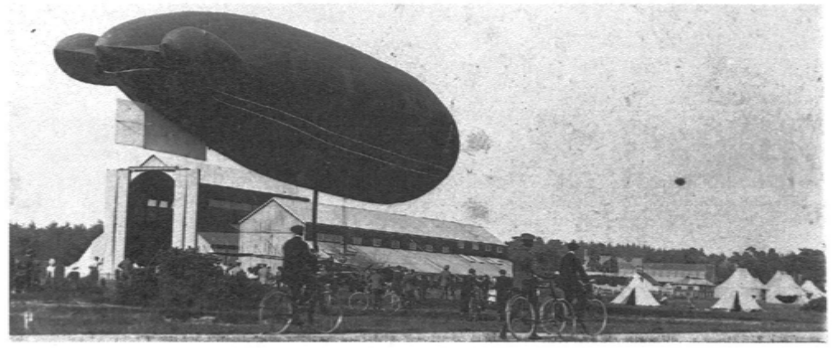
Beta II after handing over to the Navy, in whose service she was known as Naval Airship No 17.
(British Balloon Museum and Library)

On 1 January 1914, together with all other military airships, *Beta II* was handed over to the Navy, in whose hands she was known as HM Airship No 17, and after a brief period of service in France was used for training until she was finally struck off charge in May 1916.

	Baby	*Beta*	*Beta II*
Powerplant	20hp REP	35hp Green	50hp Clerget
Dimensions			
length:	84ft	104ft	116ft
diameter:	24ft 8in	25ft 0in	26ft 0in
capacity:	21,000 cu ft	33,000 cu ft	42,000 cu ft
Lift:	–	880lb	–
Speed:	20mph	26mph	32mph
Crew:	2	2/3	2/3

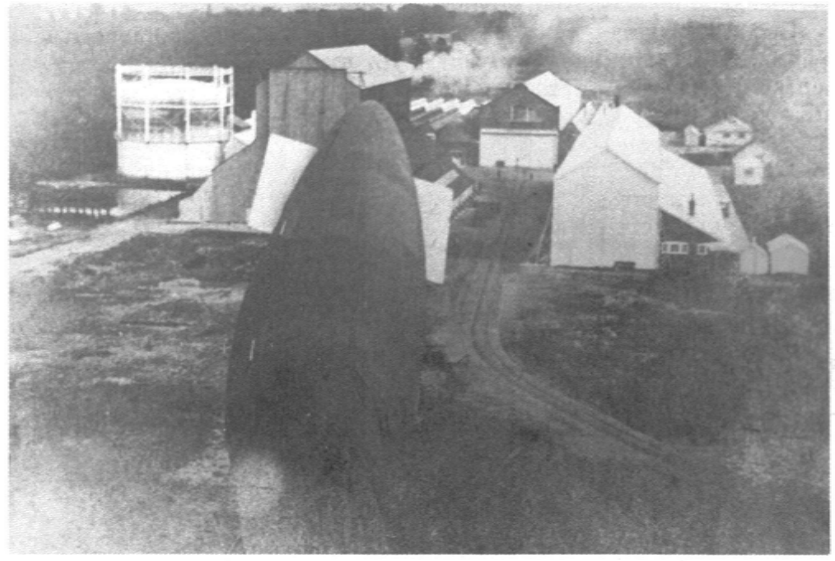
Gamma

Although Dirigible No 2 (later renamed *Gamma*) was originally conceived in 1907, her construction was not started until 1909, when the necessary funds were finally made available. The envelope was designed by the Factory, but was fabricated in France by Astra. It was made of rubber-proofed fabric, had a capacity of 75,000 cu ft and incorporated two inflated horizontal tubes at its tail, fabric being stretched between these tubes and the tapered tail of the main envelope to provide stabilising surface. The car, together with its supporting framework of steel tube and hickory, was constructed at Farnborough. *Gamma* was powered by an 80hp Green engine driving two contrarotating propellers through shafts and gears which allowed the propellers to swivel to provide an element of upwards or downwards thrust, thereby facilitating manoeuvring and conserving ballast.

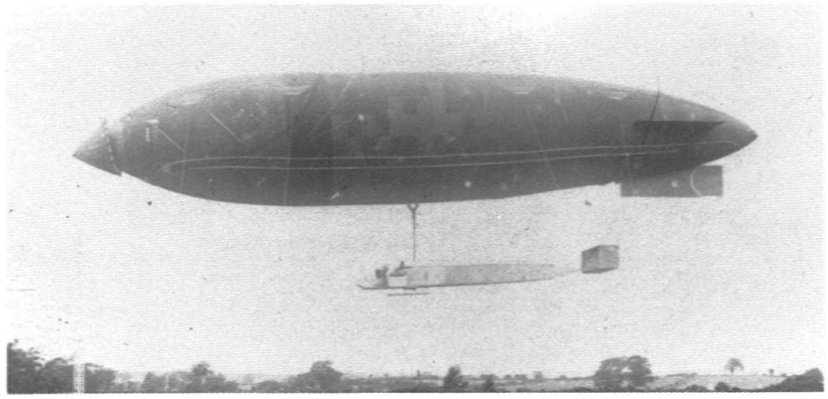


Gamma with its original tail surfaces, and with the Airship Shed in the background.
(via CH Clover)

The first flight was made on 12 February 1910, and lasted over an hour, during which time *Gamma* reached a height of more than 2,000ft. By April she had completed a number of satisfactory flights, and it was decided to deflate the envelope by means of the ripping panel provided for emergency use, thus testing its effectiveness. Unfortunately the panel proved to be defective, and although the ship was deflated with impressive speed the envelope was badly torn. While the damage was being repaired the front



This photograph, although of poor quality, is included without apology because it shows *Gamma* being 'ripped' in April 1910. The original airship shed is behind *Gamma's* tail, the Balloon Shed is to the right, and the workshop block is to the rear.

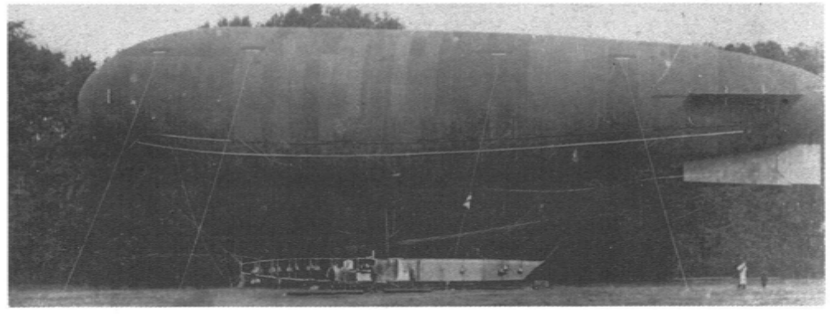


Gamma on the mooring mast.
(British Balloon Museum and Library)

elevator, which had been found superfluous, was removed, and the metal propellers replaced by four-bladed wooden units. She returned to service for a brief period before again being deflated, this time by valving off the hydrogen, so that the inflated stabilising tubes could be replaced by fixed planes of conventional configuration. The Green engine was replaced by two 45hp Iris engines of the type originally designed by Geoffrey de Havilland for his aeroplane, driving each propeller separately.

A new and larger envelope, fabricated by the airship pioneer E T Willows, was substituted early in 1912, the original having developed repeated leaks. By April she was back in service, officially renamed *Gamma II*.

Her wireless transmissions during the September manoeuvres did much to demonstrate the rôle for which airships had been intended but had little effect on the progress or outcome of the 'battles' as they were received, with equal clarity, by both sides.



Gamma II moored during the 1912 manoeuvres, after the loss of her box-kite tail.
(British Balloon Museum and Library)

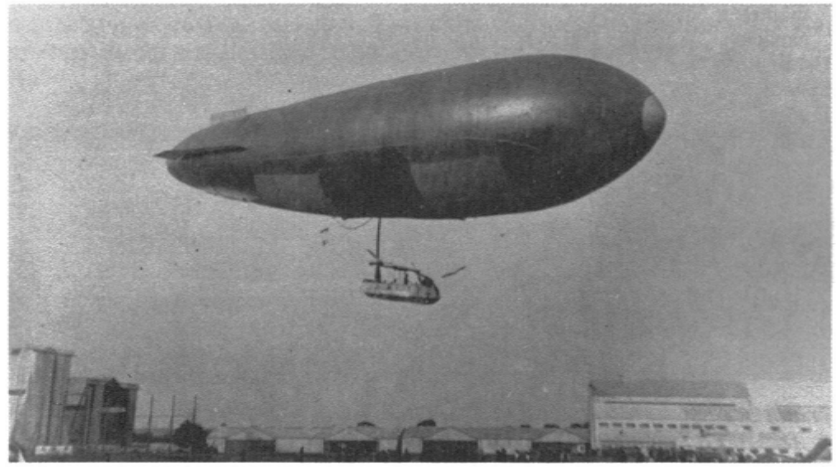
At the end of the manoeuvres her commander flew her over nearby Cambridge at night, firing off Very lights to demonstrate her potential for aerial bombardment. Unfortunately he lost his way and, rather than attempt to land in strange countryside, continued to fly until his petrol supply was exhausted and then let the airship drift with the wind until dawn, when she landed near Bristol. After refuelling he attempted to fly back to Farnborough, but one of the rudder cables broke and, out of control, *Gamma II* made a forced landing, with considerable damage to her framework.

Following repairs she remained in use through 1913 and was handed over to the Navy on 1 January 1914. Her career thereafter appears to have been limited, although she flew, and was damaged, at the 1914 Spithead review. Her eventual fate is unknown.

	Gamma	*Gamma II*
Powerplant:	80hp Green	2 × 45hp Iris
Dimensions		
length:	152ft	169ft
diameter:	30ft	33ft 6in
capacity:	75,000 cu ft	101,000 cu ft
Lift:	–	2,500lb
Speed:	30mph	32mph
Crew:	5	5

Delta

Designed in 1910, the fourth Farnborough airship was intended to have a speed of at least 32mph, a ceiling of 6,000ft, and a range of 300 miles. Head



Delta descends at Farnborough in 1913 with the aid of its swivelling propellers.
(British Balloon Museum and Library)

resistance was to be reduced as much as possible and the engines were to be chosen for reliability rather than extreme lightness.

Two frames of girder construction were attached to the underside of the envelope, running fore and aft. They were placed on either side of the envelope so that, if the envelope was ever ripped, they would fall clear of the car, thus avoiding damage or injury. The envelope was divided into five separate compartments, and horizontal and vertical stabilisers were fitted to the tail. Two 110hp White and Poppe engines were installed, driving swivelling propellers.

Delta made her first flight in September 1912, and took part in the Army manoeuvres later that month, during which her wireless transmissions were received as far afield as Thetford and Portsmouth. Upon her return to Farnborough the two stiffening girders were removed, converting her from semi-rigid to non-rigid configuration.

By 1913 her envelope was leaking badly, and was treated with a flexible nitro-cellulose dope invented by Dr Ramsbottom, chemist at the Factory. This treatment, which effectively rendered the envelope sufficiently gas-tight, was known thereafter as 'Delta Dope'.

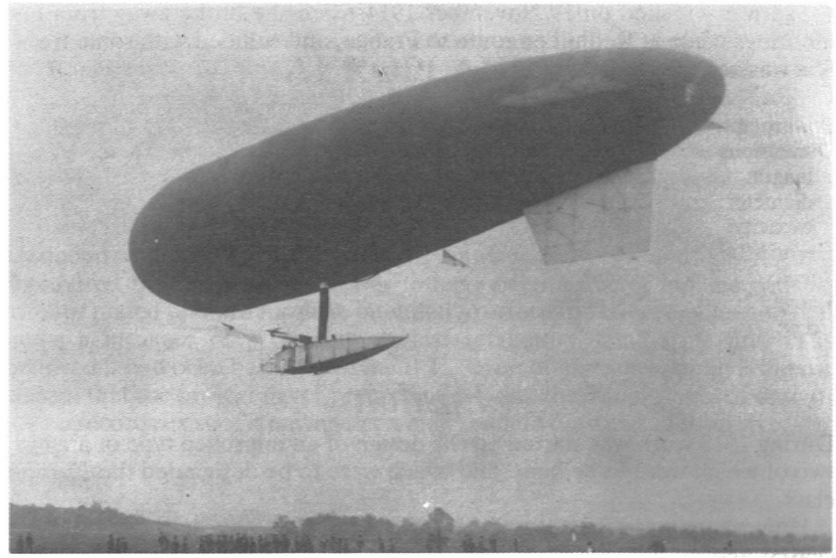
During the 1913 manoeuvres she made numerous wireless transmissions, including communication with the airship *Eta* at ranges of up to thirty miles. During October Maj E M Maitland made a parachute jump from *Delta* as she flew over Farnborough at a height of 1,800ft.

Like all the Army's airships she passed into Admiralty control on 1 January 1914, and no record has been found of her flying after August that year.

Powerplant:	2 × 110hp White and Poppe
Dimensions	
length:	198ft
diameter:	39ft 6in
capacity:	173,000 cu ft
Useful lift:	3,000lb (approx.)
Speed:	44mph
Range:	400 miles
Crew:	5

Eta

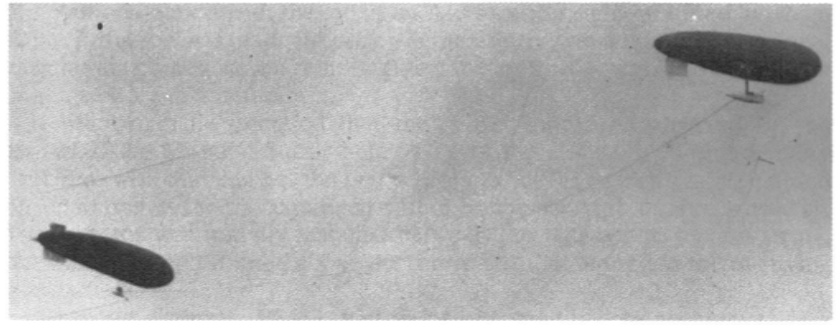
Eta, which was ordered on 5 October 1912, was another non-rigid airship, with an envelope of rubber-proofed fabric and midway in size between that of *Gamma* and the larger *Delta*. Her car was also a compromise between those of the two earlier vessels, its design falling between the long framework of *Gamma* and the short gondola of *Delta*. The car was suspended from the envelope by a wholly new system which comprised a metal 'D' ring to which the rigging was spliced and through which a number of narrow silk webbing bands were passed, then spread out fanwise and secured, both by stitching and adhesive, to a patch of fabric (later known as the 'Eta Patch') which was glued to the envelope with rubber solution. This



Eta making a descent some time after its transfer to the Navy.
(British Balloon Museum and Library)

system was used for all non-rigid airships and kite balloons up to the end of the war.

Eta was powered by two 80hp water-cooled Canton-Unné engines. She was completed on 18 August 1913, and proved completely successful. She was handed over to the RFC on 20 September, and took part in that month's manoeuvres, exchanging wireless transmissions with *Delta*. Her military career was destined to be short, for on 1 January she passed to the Navy.



Eta towing Naval Airship No 2 from Odiham to Farnborough in August 1913. This is believed to be the only occasion on which one airship has taken another in tow.
(British Balloon Museum and Library)

She was wrecked on 19 November 1914 when she broke away from her moorings while at Redhill en route to France, and collided with some trees. She was not repaired.

Powerplant:	2 × 80hp Canton-Unné
Dimensions	
length:	188ft
diameter:	33ft 6in
capacity:	118,000 cu ft
Useful lift:	2,500lb
Speed:	42mph
Range:	500 miles
Crew:	5

Epsilon

During 1913 work was started on the design of an improved type of airship, two of which were to be built, and which were to be designated the *Epsilon* class.

However, on the first day of 1914 the Army's involvement with airships ceased and all airships were handed over to the Navy. Although a small amount of material had been produced for the new ships, the work was abandoned.

AEROPLANES

A.E.1

See F.E.3.

A.E.2

Designed during 1917 and probably intended for ground attack, the Armoured Experimental No 2 was to have been a tractor biplane with an armour plated forward fuselage intended to afford the crew, engine and fuel tanks a measure of protection against retaliatory small-arms fire. It is believed it had been based upon the B.E. series of machines, but it is almost certain that the project never progressed beyond the initial stages of design, for no records exist of it having been built, and no drawings of it survive.

Wing span:	42ft 7in

A.E.3

This armoured two-seater, which was almost certainly the last aeroplane to be designed at Farnborough, has the obscure distinction of being the only Royal Aircraft Factory type to bear an official name. Under the system of nomenclature which was adopted by the Royal Air Force towards the end of the war it became the Farnborough Ram.

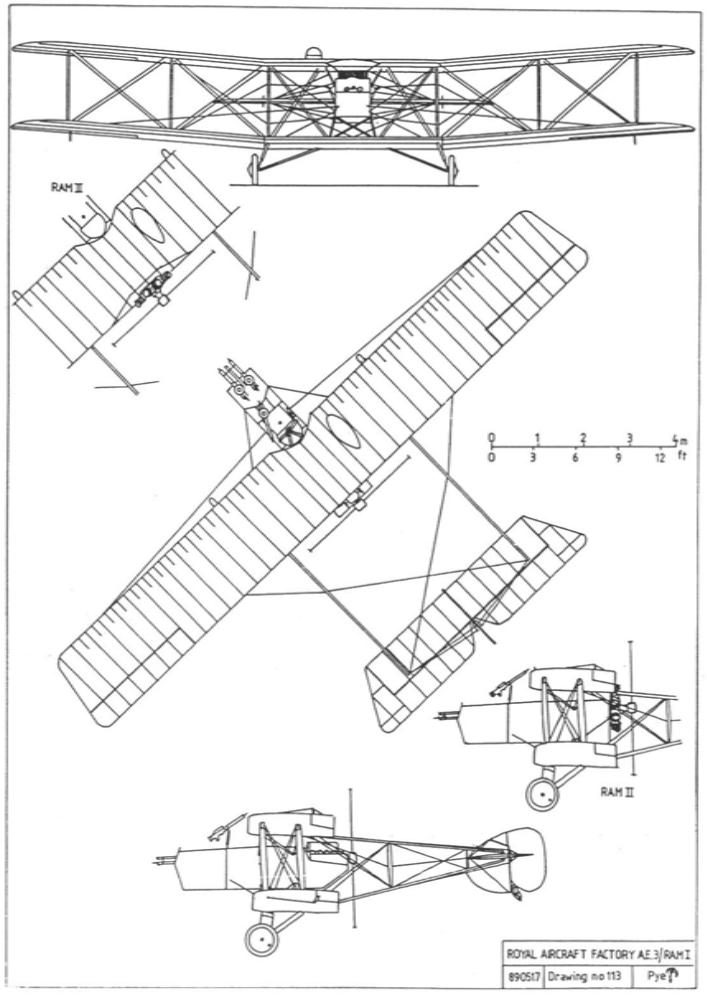
Intended primarily for ground attack, the A.E.3 was a pusher biplane developed from the N.E.1, with which it shared its undercarriage, outer wing panels and horizontal tail surfaces. Its nacelle, containing the crew and engine, was protected by steel armour plate, the floor having two skins, the inner being 5 gauge and the outer 10 gauge. The armament comprised three Lewis guns, two firing forward and a third on a telescopic mounting for defence against attack from behind. The forward-firing pair were coupled together and aimed with the aid of an Aldis optical sight mounted between them. Provision was made for no fewer than thirty-two double Lewis drums, each holding ninety-seven rounds, giving the crew what was, at that time, an immense store of ammunition.

It was originally intended that the A.E.3 should be powered by the geared 200hp Hispano-Suiza, but, owing to the almost unending delivery problems with that engine, the first prototype, B8781, which was completed on 28 March 1918, was equipped with a Sunbeam Arab of similar power. The radiator was initially installed between the rear centre-section struts, but was soon repositioned above the centre-section, alongside the overwing gravity tank.

A second example, B8783, had its nacelle modified to accommodate a 230hp Bentley B.R.2 rotary engine. Designated Ram II, it was completed by the end of May. The third machine, B8782, another Arab powered Ram I, was completed a few days later.

The flight trials of B8783, which began on 4 June, revealed that the control response was barely adequate, and by the 30th, when the machine went to France for service trials, the rudder and ailerons had been replaced by surfaces of increased area. The aircraft was tested by crews from both 201 and 209 squadrons before returning to Farnborough on 20 July. At the same time B8781 underwent armament trials at the testing station at Orfordness.

In common with many of the Factory's less-inspired designs, the A.E.3 found little favour with its intended users, service reports being best described as 'unenthusiastic'. No production orders were placed, especially as its intended rôle would clearly be better filled by more conventional designs such as the Sopwith Salamander.



The design of a further version, the Ram III with wings of increased chord, for which the more plentiful 150hp B.R.1 had been suggested as a powerplant, was not completed.

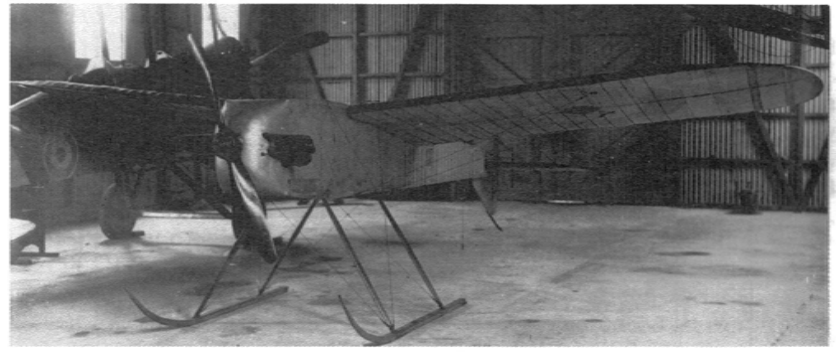
Dimensions					
span	47ft 10in;	length	27ft 9in;	height	10ft 0in;
chord	6ft 0in;	gap	5ft 6in;	wing area	560 sq ft;
dihedral	5°.				
Performance:					
maximum speed	95mph (estimated).				

Aerial Target

Conceived late in 1916, this was a radio-controlled, pilotless aeroplane intended both for defence against Zeppelins and as a flying bomb. In the former rôle it was planned that it would be controlled from the ground, but in the latter rôle control from an accompanying manned aeroplane was also considered. To disguise its intended purpose it was always referred to as the Aerial Target.

Its wireless apparatus was designed by Capt Archibald M Low of the RFC's wireless unit at Feltham, whose idea it was. His attempt to build the aeroplane himself, largely from spare parts, had met with no success, and the assistance of the Royal Aircraft Factory had therefore been requested. The project was undertaken by Henry Folland, although much of the detail work was drawn by his assistant, H E Preston. The Farnborough design was a small shoulder-wing monoplane powered by a two-cylinder ABC Gnat of 35hp, with numerous radio aerials running vertically down the fuselage sides and chordwise across the wings. In the interests of simplicity, lateral control was by wing warping, and generous dihedral ensured lateral stability.

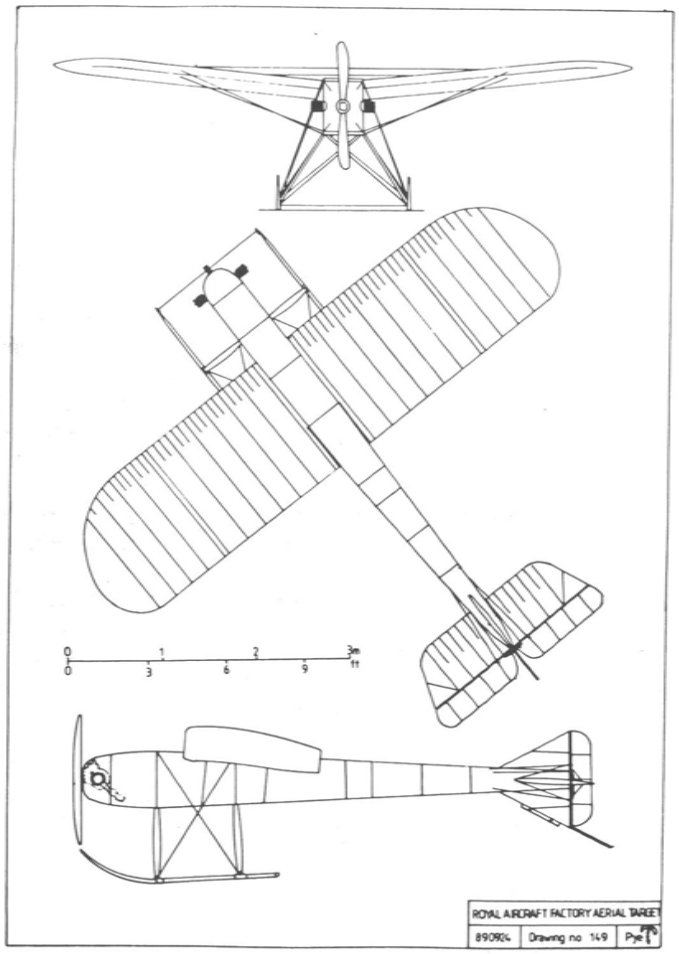
Six examples, A8957–A8962, were constructed, the first being delivered



The Aerial Target. Note the aerial wires running vertically down the rear fuselage and chordwise on the wings.
(JM Bruce/GS Leslie)

to RFC Northolt, where the trials were to take place, on 5 June 1917. The intention was that the machine should be trimmed to take off and climb away to a reasonable height before radio control was attempted. Extensive windtunnel tests on models had indicated what the necessary tailplane incidence should be, but the first flight, on 6 July, consisted of an almost vertical climb away from the launching rail, followed by the inevitable stall and consequent crash, before the radio control system could take effect. It was clear that the still imperfectly understood aerodynamic differences between scale models and full-sized aeroplanes had resulted in insufficient tailplane incidence.

A second example was tested on 25 July but failed to take off, merely running along the ground until its undercarriage finally collapsed, the tailplane adjustment having been somewhat overcorrected. A third



attempt, with the tailplane finally set at the correct angle, was made three days later, but unfortunately resulted in yet another crash when the engine failed just after take-off. Although damage was confined to a broken propeller and some easily repaired undercarriage components, official interest in the project appears to have diminished and no further trials are recorded as having taken place, although the project was resurrected briefly in the early 1920s.

One example was later converted to a manned aeroplane by No 3 (Western) Aircraft Depot at Bristol, and was fitted with a wheeled undercarriage and ailerons. As a rebuilt aircraft it was allotted a serial number from a batch allocated for that purpose. It received the number B8962, with numerals similar to those of its original, uncertain identity, and this has caused much ill-founded conjecture among latter-day historians.

By 1934 it had been disposed of, and was owned by Mr Ron Shelley of Billericay, but it was broken up without appearing on the civil register.

Dimensions:

span	22ft 0in;	length	20ft 4in;	height	5ft 10½in;
chord	5ft 2in;	incidence	6°;	dihedral	5°.
Weight	500lb.				

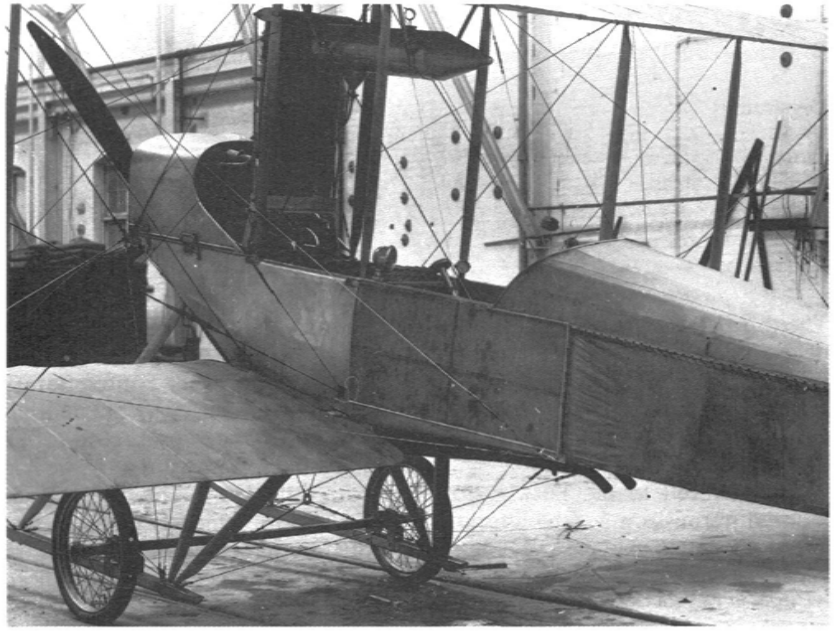
B.E.1

The third machine in the Factory's initial research series, each of which was of a distinct and separate type, was a tractor biplane. It was named the Blériot Experimental Number 1, or B.E.1. As with other contemporary Farnborough designs, it was ostensibly a reconstruction of another aeroplane, in this case a Voisin which had originally been presented to the War Office by the Duke of Westminster and which, following a crash, had been delivered to the Factory for repair in June 1911. The War Office granted permission for the alterations and additions which O'Gorman had suggested on 12 August 1911, but it is probable that design work, most of which was carried out by Geoffrey de Havilland, was already well advanced by that date.

Only the Voisin's engine, a water-cooled Wolseley V-8 developing a nominal 60hp, its radiator, and possibly a few metal fittings were actually used in the construction of the new machine, which was a two-bay biplane. Its upper wing was of slightly greater span than the lower, the wings originally being rigged with neither stagger nor dihedral. The large, low-aspect-ratio tailplane was of true aerofoil section, contributing to the overall lift, but was set at a smaller angle of incidence than the mainplanes to provide longitudinal stability. It was fastened directly to the upper longerons. The ear-shaped rudder hung from an unbraced sternpost, and there was no fin. Lateral control was by wing warping, the control column being of generous height to give the pilot good leverage and thereby reduce control forces to a level designed to eliminate fatigue.

The fuselage had decking behind the rear seat only, none being provided

behind the engine or between the tandem cockpits. The passenger was placed in the forward seat, very close to the centre of gravity, so that no trim changes would occur when the machine was flown with two aboard. The radiator was mounted on the forward centre-section struts, where it benefited from the full force of the slipstream to achieve the necessary cooling with the minimum possible weight of water. The comparative quietness of the water-cooled engine, which was enhanced by the inclusion of silencers in its long exhaust pipes, led to the B.E.1 being dubbed the 'Silent Army Aeroplane'. The undercarriage incorporated long ash skids, intended to prevent the propeller tips touching the ground when the tail was raised, and the tailskid was fully swivelling, allowing a remarkably small turning circle on the ground.



The B.E.1, apparently complete, inside the Factory workshops on 1 October 1911. Its first flight was not made until 4 December.
(Royal Aerospace Establishment)

Although photographs taken inside the workshop (known today as the Q27 building) in October 1911 show the aeroplane apparently complete, it did not make its first flight until 3.30pm on 4 December, when de Havilland took it up for a brief circuit, for which he was rewarded with two shillings and sixpence (12½p) in flying pay. He reported that he was satisfied with the aeroplane, but less than happy with throttle control provided by the Wolseley's carburettor, and recommended the substitution of a Claudel unit. This may have been a more complex modification than de Havilland

This photograph of the B.E.1, taken on Farnborough Common, bears the contemporary caption 'The Silent Army Aeroplane'. The wheel tracks demonstrate the machine's impressively small ground turning circle.

had imagined, because the machine did not fly again until 27 December, when, with the new carburettor installed, he made six short flights, several of them with a passenger. The maximum speed was found to be 55mph, although the engine was not achieving the 1,200rpm stated to be its maximum output (it never did so, despite continual attention).

De Havilland considered that the elevator operating mechanism was too coarsely geared for ease of control, tending to over-correct, and asked for it to be geared down, but otherwise he thought the aeroplane's stability to be good. He also expressed the opinion that too much weight was carried by the tailskid, lengthening the take-off run and, as a consequence, the wheels were repositioned twelve inches to the rear before the aircraft made its next flights, on the first day of the new year, when Mervyn O'Gorman occupied the front seat for two short flights.

By 7 January 1912 the top wing had been re-rigged with three inches of backstagger, presumably to move the centre of pressure slightly to the rear, and a scoop had been fitted in the front of the carburettor's air intake, a measure which increased engine speed by approximately 100rpm to about 1,100rpm.

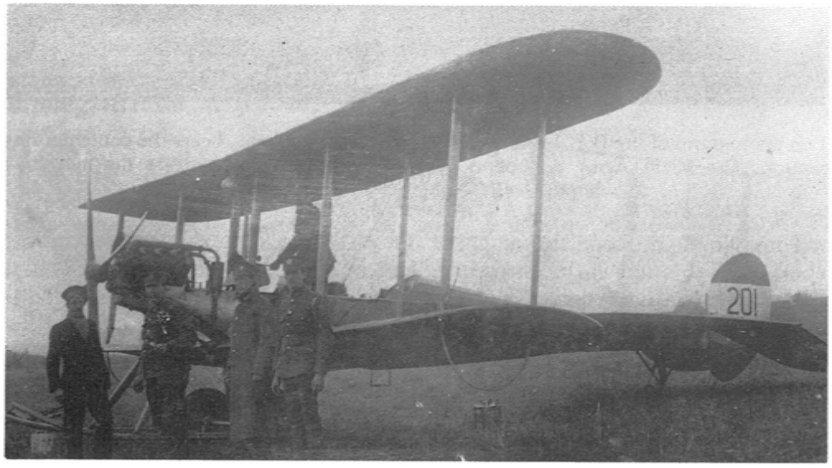
On 10 January one degree of dihedral was given to each wing panel (an included angle of 178°), and two days later the aeroplane was tested with a Zenith carburettor, which was found to be much less flexible than its predecessor. De Havilland ran out of petrol during the tests, but accomplished the forced landing without mishap. Next day the Claudel was refitted and the B.E.1 was timed at 59mph over a measured three-quarter-mile course, with both seats occupied.

On 20 January, in a final attempt to improve engine performance, the propeller tips were cut down, producing an engine speed of 1,150rpm. This was the best ever achieved, although it was still just short of the maker's stated figure.

Throughout the remainder of January de Havilland flew the B.E.1 on numerous occasions, carrying many passengers, and he appears to have been completely satisfied with it. He did not suggest any further changes,

and flew it in winds of up to 25mph before turning his attention to its twin sister, the B.E.2, which was completed by 1 February 1912.

On 11 March the B.E.1 was formally handed over to Capt C J Burke of the Air Battalion, Royal Engineers. Burke flew it for the first time three days later—the day on which the document which has come to be regarded as the first Certificate of Airworthiness was issued, certifying that the B.E.1 had been fully tested by the Factory.



The B.E.1 after the installation of a Renault engine in place of its original Wolseley.
(The late Flt Lt Kenneth R Nash RAF, via Mrs JP Nash)

The machine was given the serial B7, and the following month it became the property of No 2 (Aeroplane) Squadron of the newly formed Royal Flying Corps. In August its serial was changed to 201, an identity it retained throughout the remainder of its long career.

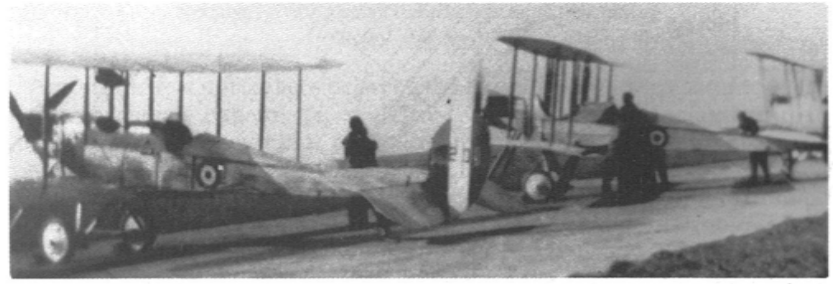
A heavy landing on 31 March 1912 resulted in the B.E.1 being returned to the Factory to be fitted with a new undercarriage. It was also fitted with a compass and an aneroid altimeter. On Thursday 11 April it suffered engine failure while being test flown by Mr Perry, and a wingtip was damaged in the ensuing forced landing. This was soon repaired, and the aeroplane was test flown by de Havilland at 6.00pm the following day. Following some alterations to the elevator cables, it was again test flown on 15 April before being returned to the RFC.

A further engine failure, on 28 May, led to its again being returned to the Factory. As its Wolseley engine was considered to be beyond economic repair, it was replaced by a Renault similar to that in the B.E.2. This engine, being air-cooled, allowed the removal of the radiator from the centre-section struts, with consequent improvements in performance and in the crew's forward view.

Following a test flight by de Havilland on 22 June, 201 was handed back to the Flying Corps, seeing service with No 4 and, later, No 5 Squadron. By

the end of 1913 it had amassed a total of 172 flying hours. It had made several visits to the Factory for minor repairs, and had acquired fuselage decking ahead of, and between, the cockpits, making it virtually identical to contemporary B.E.2s. This similarity was further enhanced when its tailplane was replaced by one of slightly reduced area which had become the standard B.E.2 fitting at that time.

At the outbreak of war the B.E.1 was not sent to France, as were most of the RFC's effective aircraft, but remained with a training unit in England. Following a crash in January 1915 it was returned to Farnborough once more for repair, and was reported as still being there the following May. It is recorded as having been at the Central Flying School as late as July 1916, although by that date it had again been rebuilt and had acquired a B.E.2b-type fuselage.

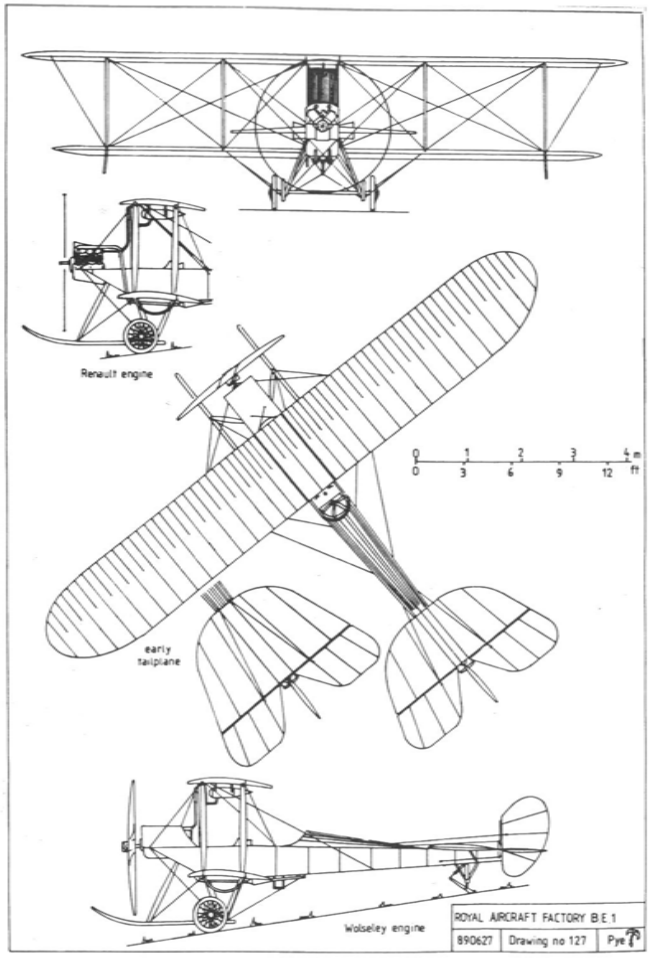


The aeroplane nearest to the camera is almost certainly 201, the B.E.1, seen here late in its life, by which time it had acquired a B.E.2b-type fuselage.
(JM Bruce/GS Leslie)

The eventual fate of the B.E.1 is unknown. It merely fades from official records into an obscurity wholly undeserved by the 'revered grandfather of a whole brood of Factory aeroplanes'.*

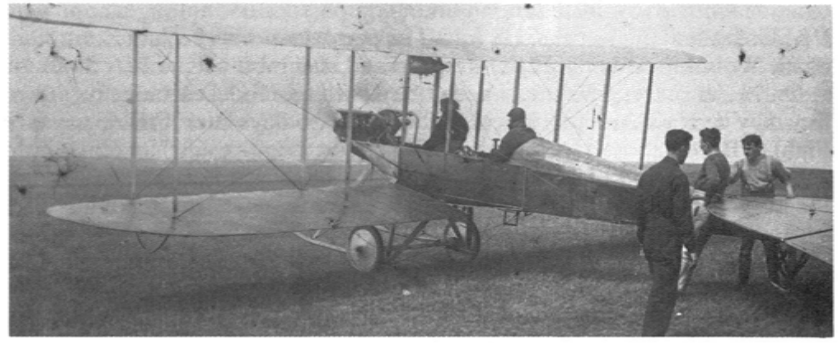
Powerplant:	60hp Wolseley V-8 (later 60hp Renault)
Dimensions:	
span	38ft 7½in (upper); 34ft 11½ in (lower);
chord	5ft 6in;
gap	6ft 0in
wing area:	374 sq ft
length	29ft 6½in
height	10ft 2in
Performance:	
(Wolseley)	
max speed	59mph (at sea level)
min speed	42mph
climb	155ft/min (to 600ft).

* Sir Walter Raleigh & HA Jones, *The War in the Air* (Oxford University Press, 1922).



B.E.2

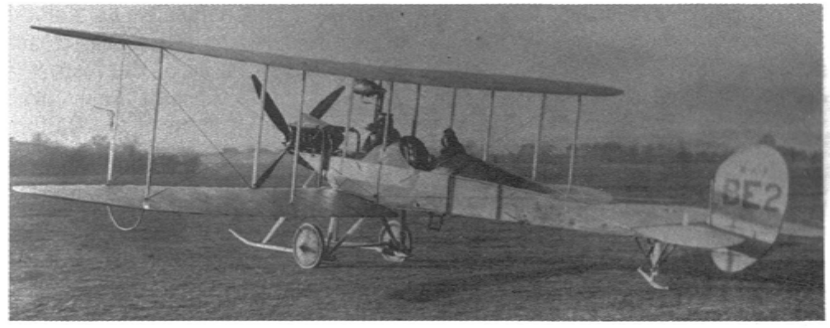
The B.E.2 was virtually a copy of the B.E.1, except that it was powered, from the start, by a 60hp Renault V-8 air-cooled engine. Its designation was not intended to identify it as a separate design, but merely to denote that it was the second machine built in the general-purpose tractor, or Blériot Experimental, class. Construction of the B.E.2 was well advanced before the B.E.1 flew, the 'reconstruction' subterfuge again being used to explain its origins. Both the ill-fated S.E.1 and a damaged Breguet were named, on different occasions, as the parent aeroplane, although the latter seems more likely as it did, at least, have a Renault engine.



The original B.E.2 as it first appeared. Note how the exhaust pipes pass within the fuselage, giving a small reduction in head resistance.
(Imperial War Museum)

Among the few differences between the two B.E.s was the routeing of the newer machine's exhaust pipes down through the fuselage rather than outside it, achieving a minor reduction in drag, albeit at the expense of a consequent increase in fire risk. The B.E.2's undercarriage incorporated radius rods to locate the axle positively, particularly against longitudinal movement, and the wheel spokes were fabric covered, an innovation which not only reduced their resistance but was considered by de Havilland to 'damp out lateral oscillations'. The undercarriage skids were shorter than those of the B.E.1, lacking the long projection ahead of the propeller.

The B.E.2 made its maiden flight on 1 February 1912, with de Havilland at the controls. He appears to have judged it entirely satisfactory as built, for no modifications are recorded to have been required. This is not altogether surprising when it is remembered that all the necessary development work had effectively been carried out during the testing of the B.E.1.



The original B.E.2 modified to include decking between the cockpits. The exhaust pipes are now fully external, whereas they had initially passed through the fuselage. The pilot is Geoffrey de Havilland. Note that the undercarriage skids are shorter than those of the B.E.1.

De Havilland lost little time in taking up passengers, among whom were F M Green and S Hiscocks. He found its performance to be superior to that of the Wolseley-powered B.E.1 in speed and in climb.

On 21 February, after it had been fitted with a Claudel carburettor, it was flown by de Havilland to a height of 2,600ft. Two days later it made a return flight to Brooklands, covering about fifty miles.

Towards the end of March a wireless set which had been constructed at the Factory was installed in the B.E.2. Experimental transmissions were started on the 26th, but were curtailed when the equipment broke down. The result of further tests on 28 March and 1 and 2 April were described as good, and for the next week or so numerous passengers were taken up so that they could sample the novelty of airborne wireless for themselves. By 1 May a new amphibian undercarriage having both floats and wheels had been fitted, but it was found to be unsuitable for 'rolling' (taxying) and was removed. Two days later power had been increased by the fitting of a 70hp Renault, and the B.E.2's speed was measured at 68mph.

On 11 May the machine was flown to Fleet Pond, where the floats were refitted, but the trials were inconclusive because their draught proved too great for the pond and the tail float was found to be set at too small an angle. Modifications were completed by the evening, and a short flight from the water was made, but the floats were damaged on landing. It seems probable that they were not repaired, as no record has been found of any further trials with this undercarriage.

On Friday 17 May de Havilland flew the B.E.2 before the King and Queen in company with some other machines, as part of His Majesty's official review of the armed forces, and on the 31st he climbed it to 6,050ft in fifteen minutes.

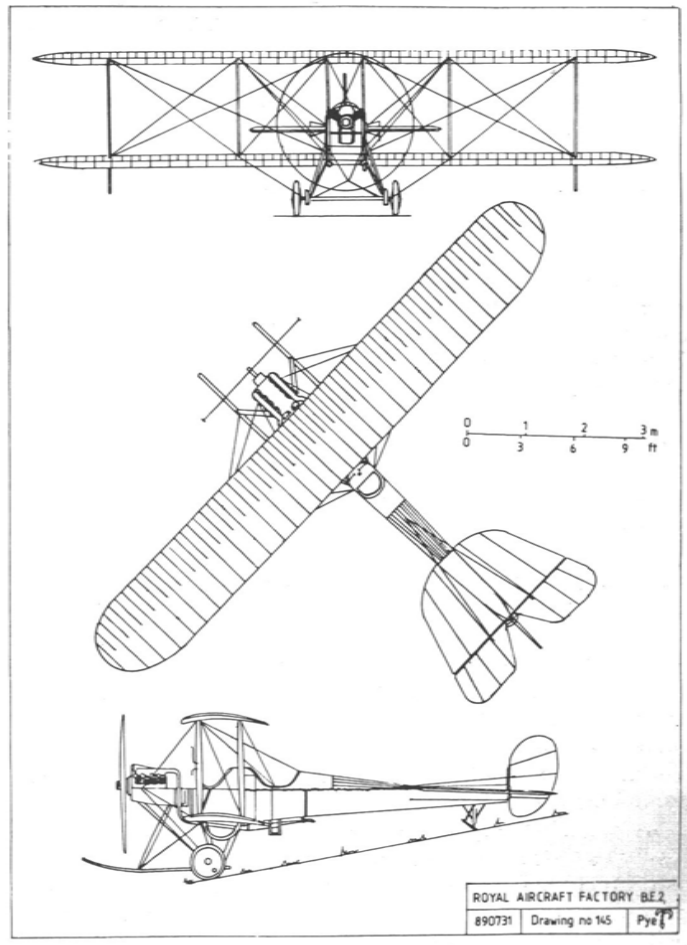
By early the following month the B.E.2 had flown more than 500 miles since being fitted with the larger engine, and it continued to be used almost every day for tests of one kind or another.

During the second week of August de Havilland flew the aeroplane to Larkhill, on Salisbury Plain, where the Military Aeroplane Trials were taking place. Because Mervyn O'Gorman, in his capacity as Factory Superintendent, was one of the competition judges, the B.E.2 was clearly ineligible for the competition, but it still undertook many of the tests *hors concours* and achieved overall results at least equal to those of the eventual winner, the massive Cody 'Cathedral' (itself a development of the Balloon Factory's British Army Aeroplane No 1, built at Farnborough four years previously). Its use as a general 'hack', taking officials and pressmen to and fro throughout the trials, did a great deal to convince observers that aviation had reached a level of practicality which had been previously unappreciated.

On 12 August de Havilland, accompanied by Maj F H Sykes, took off at about 5.00am and, in the still, cool air of early morning, decided to test the B.E.2's climbing powers to the full. They eventually reached an altitude of 10,560ft, capturing the British record not only for flights with a passenger, but for solo flights as well.

Although the purpose of the Military Trials was to decide with which

machine the RFC should be equipped, the B.E.2 was clearly more suitable than the actual winner, and the War Office decided to adopt the Factory's creation. Although a few further examples were built at Farnborough, much to the chagrin of C G Grey, orders were placed with private constructors such as the British and Colonial Aeroplane Company and Vickers. All such production machines appear to have been designated B.E.2a.

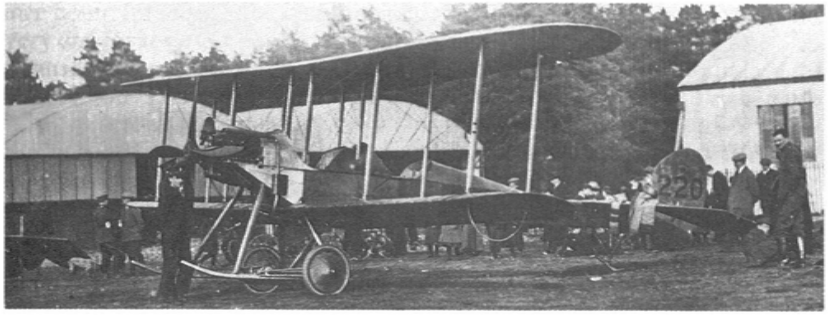


Powerplant:	60hp Renault V-8; 70hp Renault V-8
Dimensions:	
span	38ft 71⅛in (upper); 34ft 11⅝in (lower);
chord	5ft 6in;
gap	6ft 0in;
wing area	374 sq ft;
length;	28ft 4in;

height	10ft 2in;
propeller diameter	8ft 10in;
wheel track	6ft 2in;
tailplane span	11ft 0in;
tailplane area	52 sq ft;
elevator area	25 sq ft;
rudder area	12 sq ft.
Weight:	1,700lb (loaded).
Performance:	
max speed	(70hp) 70mph at sea level;
min speed	40mph;
climb	244ft/min to 1,000ft (60hp);
	305ft/min to 1,000ft (70hp);
glide angle	1in 6¼.

B.E.2a

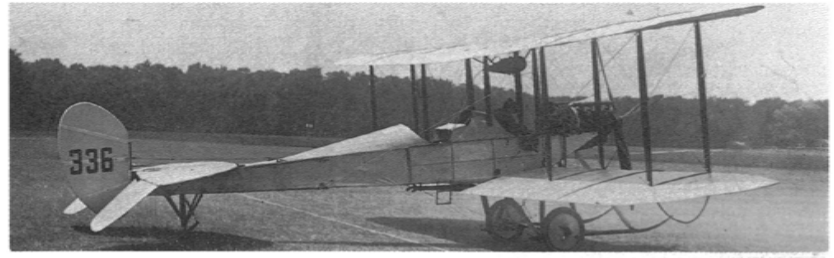
It now seems certain that the designation B.E.2a was applied to all production B.E.2s, or to those built by contractors, rather than to any specific variant, for the earliest examples were almost identical to the prototype, certain modifications being made later without any change in designation. The 'a' suffix was not consistently applied in service use, but this did not cause any confusion at the time because virtually all the B.E.2s were 2as. Drawings bearing the title B.E.2a are dated as early as February 1912, the type is described in R & M 66, dated 12 June 1912, and the first production order was placed in August 1912, apparently before the final result of the Military Trials was known.



A Farnborough-built B.E.2a, showing the decking behind the engine introduced on this model.

These early machines had unequal-span wings of NPL3a section and large lifting tailplanes exactly similar to that of the original B.E.2, the only discernible difference being the addition of a fuselage decking between the seats. Later examples, which formed the majority, had equal-span wings of a new aerofoil section which allowed a deeper rear spar and required an

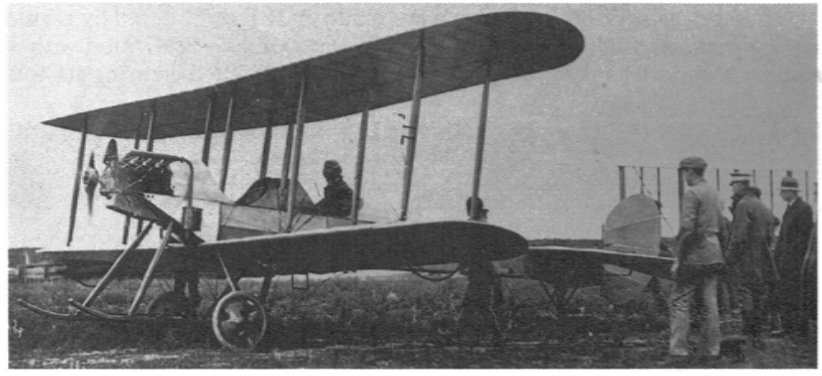
angle of incidence of only 3½°, compared with the 4½° of the earlier wing, resulting in a reduction in drag without any loss of lift. Their tailplane area was reduced, the spar remaining the same to allow the original elevators to be used, and the chord being reduced to give a surface which was roughly semicircular in planform. The upper fuselage decking remained at its original length, resulting in a small flat area immediately in front of the tailplane. The new tailplane was designated T.P.2, the original surface retrospectively becoming T.P.1



An immaculate Vickers-built B.E.2a. The purpose of the box-like structure in the pilot's cockpit is not known.

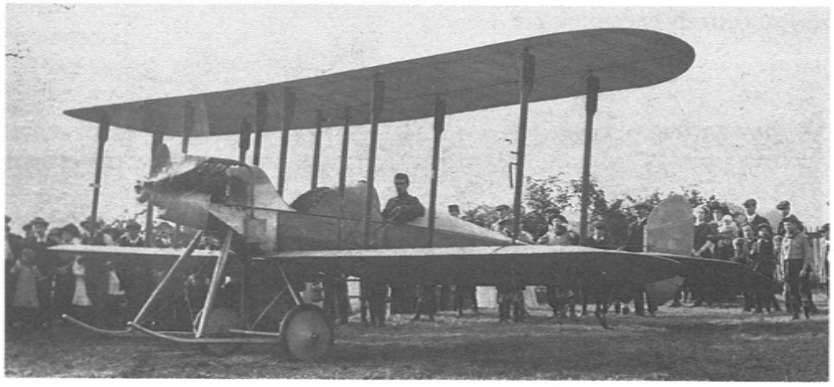
Total production of the B.E.2a cannot now be quantified exactly, but appears to have been just short of 100 machines. Nevertheless, it was still the most numerous single type on the strength of the diminutive prewar RFC. Several B.E.2as served with the Royal Naval Air Service and, in addition, the type saw service in India and with the Australian Air Service. It also provided the Royal Aircraft Factory with a reliable test vehicle of reasonable performance and predictable handling with which to conduct its wide-ranging aeronautical research.

As part of E T Busk's investigations into aeroplane stability one B.E.2a,



A B.E.2a at Point Cook, Australia, in 1914. The pilot is Lt Williams (later Air Vice Marshal Sir Richard Williams).

No 601, was fitted with two small fins on its upper wing, immediately over the centre-section struts. A high-aspect-ratio tailplane of rectangular planform was also fitted, braced to an inverted vee-shaped kingpost on the fuselage centreline. Known as T.P.3, it had a similar area to its semicircular predecessor, T.P.2, but was of a symmetrical aerofoil section and provided no lift in the normal flying position.

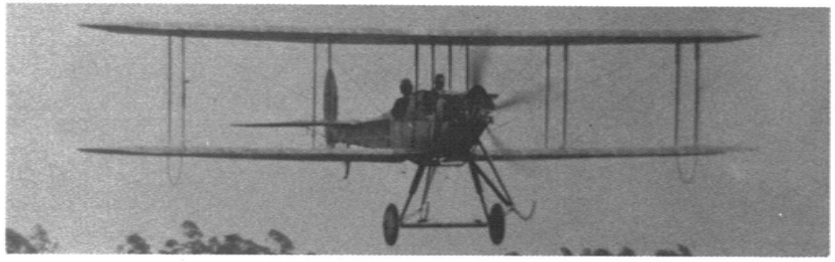


A B.E.2a fitted with experimental interplane struts designed to provide additional fin area.

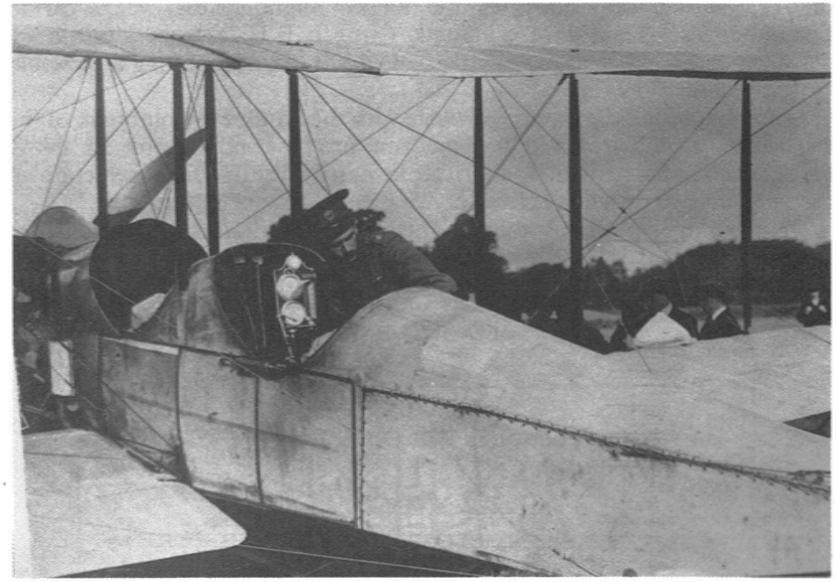
In another experiment, possibly connected with that above, No 206 (which had started its life as the B.E.6) was fitted with interplane struts which had greatly increased chord at their upper end, and were known as 'fin struts'. This aircraft was also fitted with an experimental oleo undercarriage, but appears to have reverted to its original unit.

The type also continued the wireless development tests started with the original B.E.2, aircraft 240 and 336 being among the machines chosen to carry the primitive equipment aloft.

A number of spectacular flights were made by B.E.2as piloted by regular service personnel. Number 218, a Bristol-built example, was fitted with an additional petrol tank in its faired-over front cockpit, increasing its total



A B.E.2a fitted with an experimental oleo undercarriage. It also has the 'fin struts' whose increased area can be seen at their upper ends.



B.E.2a 225 photographed after crossing from Ireland on 26 September 1913. The simple instrument panel, which contained a revolution counter, an airspeed indicator, an altimeter, and a watch, was combined into a single unit manufactured by Elliot Brothers.

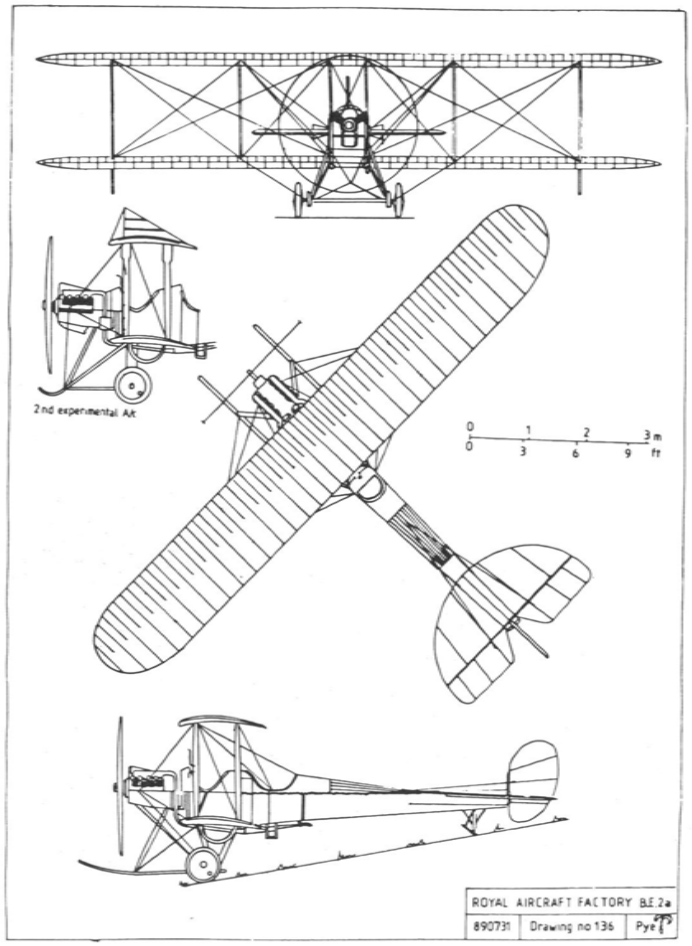
capacity to about fifty-four gallons. On 22 November 1913 it was flown by Capt Longcroft of No 2 Squadron from their base at Montrose directly to Portsmouth, and then, without stopping, back to Farnborough, covering a total of 560 miles in 7hr 20min. This prodigious achievement won Longcroft

B.E.2a 218 with an additional fifty-four-gallon petrol tank in its faired-over front cockpit, used by Capt Longcroft for several long-distance flights.
(via PHT Green)

the 1913 Britannia Trophy for the longest flight of that year. On 13 December 1913 Capt J M Salmond, flying a B.E.2a from Upavon on Salisbury Plain, reached an altitude of 13,140ft, thereby setting a new solo British record.

A number of B.E.2as went to France with the RFC at the outbreak of the war. One of them, a No 4 Squadron machine piloted by Lt G W Mapplebeck, shared with Joubert de la Ferté's Blériot the distinction of carrying out Britain's first active-service reconnaissance.

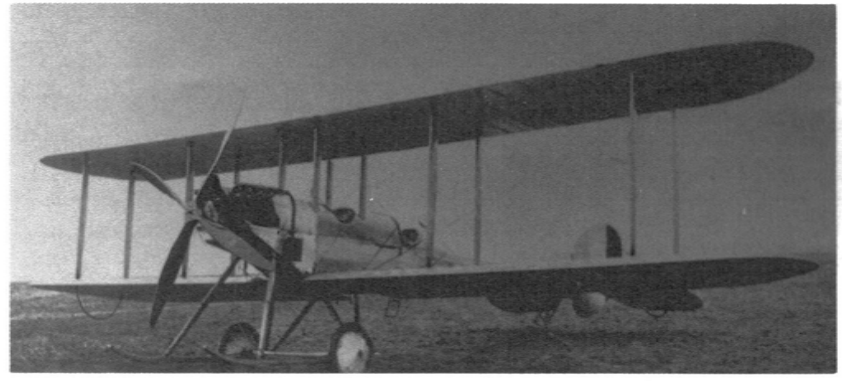
Despite this, and many other invaluable contributions to the conduct of the war, the B.E.2as were rapidly replaced by more recent designs and returned to England, where they gave equally useful service with training establishments.



Powerplant:	70hp Renault V-8
Dimensions:	
span	36ft 11⅛in;
chord	5ft 6in;
gap	6ft 0in;
wing area	376 sq ft;
stagger	minus 2in;
dihedral	2°;
length;	28ft 4in;
height	10ft 2in;
tailplane area	34 sq ft;
Weights:	1,100lb (empty); 1,600lb (loaded).
Performance:	
max speed	74mph at sea level;
endurance	3hrs;
climb	9min to 3,000ft; 30min to 6,000ft.

B.E.2b

The B.E.2b was developed early in 1914 to afford its crew better protection from the elements, and had a modified fuselage top-decking with shallower cockpit cutouts. The rudder and elevator control runs were also revised, but in all other respects the B.E.2b was similar to the earlier model. It was built by a number of contractors. After the outbreak of war comparatively large orders were placed, several with companies not then experienced in large-scale production and, although some machines were eventually completed as B.E.2cs, the last B.E.2bs were finally delivered to the RFC in February 1917. By that time they had long been superseded by later variants



A B.E.2b, showing the reduced size of the cockpit cut-outs which gave improved weather protection. This particular example appears to have been rigged without dihedral. *(via Tim Mason)*

This B.E.2b, 2781, was one of a batch built by Jonques, some of which may have been completed as B.E.2cs.

which were themselves already approaching obsolescence.

Although it was usually unarmed, except perhaps for a revolver or service rifle carried by the observer, the B.E.2b was occasionally equipped to carry a few small bombs. The first Victoria Cross to be awarded to an airman was won by the pilot of B.E.2b 687, Lt W B Rhodes Moorhouse of No 2 Squadron, who, on 26 April 1915, carried out a bombing attack on the railway station at Courtrai. Although he received numerous wounds from retaliatory ground fire, he managed to bring his machine back. His injuries later proved fatal.

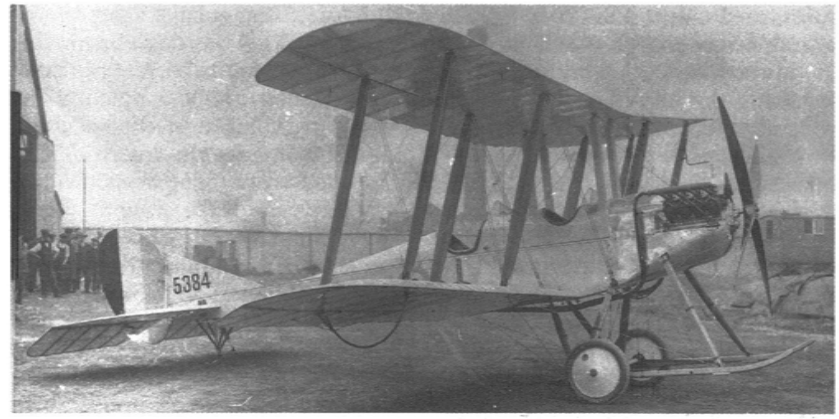
The B.E.2b remained in use with training squadrons, albeit in ever-diminishing numbers, right up to the Armistice. Several machines were fitted with components such as fins, sump cowlings and even undercarriages from later variants, either as 'improvements' or because the correct spares were no longer available.

Dimensions as B.E.2a.

B.E.2c

Representing the culmination of E T Busk's investigation into aeroplane stability, the B.E.2c was so different from earlier B.E.2 variants as to be almost a totally new design, yet it retained an obvious family resemblance to its forebears.

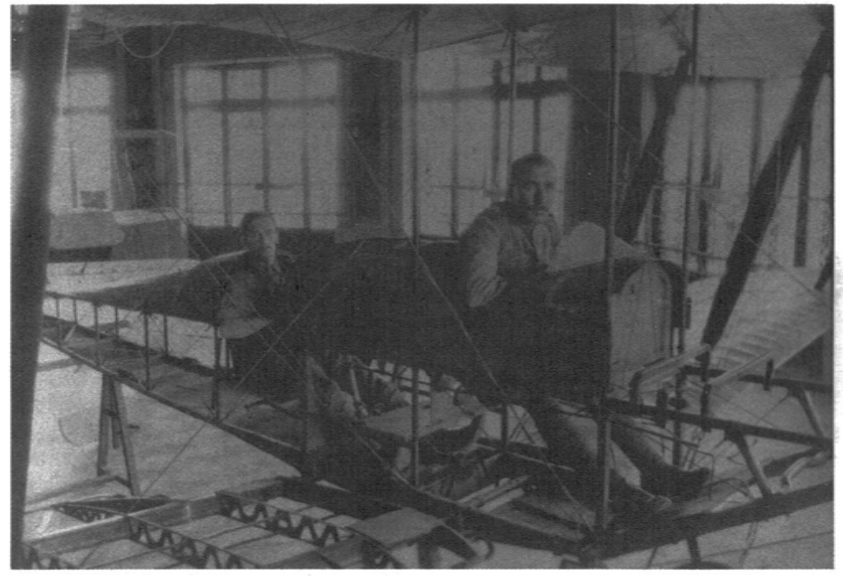
Before and immediately after the outbreak of the First World War inherent stability was almost universally considered to be the most desirable attribute of an aeroplane employed in reconnaissance, the primary function of most military machines at that time. A mount which possessed true inherent stability freed its pilot from the need to make constant control



A beautifully finished Renault-powered B.E.2c, the first of a batch built by Wolseley Motors.
(PHT Green)

inputs, and allowed him to concentrate his attention upon his military duties.

To achieve this desirable quality in the Royal Aircraft Factory's most popular design, Busk took production B.E.2b 602, added a triangular fin,

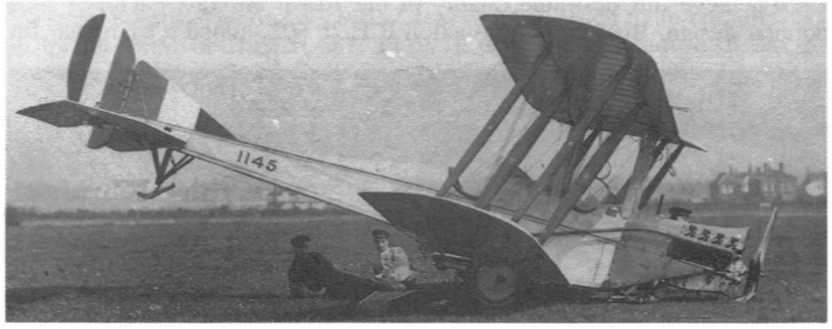


An early B.E.2c in use as an instructional airframe. The wing construction is typical of the early R.A.F.6 aerofoil section wings.
(The late Flt Lt Kenneth R Nash via Mrs JP Nash)

substituted a new non-lifting tailplane of almost rectangular planform, and introduced twenty-four inches of positive stagger. This was done by moving the lower wing back to return the centre of pressure to its correct position, following the loss of the lift previously contributed by the tailplane. The wing structure was almost totally new, being of R.A.F.6 aerofoil section, with ailerons replacing the wing-warping used in previous models. The dihedral angle was increased to 3½°, and cutouts were made in the trailing edge of the lower wing roots to restore the pilot's view of the ground.

Busk took the converted 602 for its first flight on 30 May 1914, and thereafter made numerous short flights to enable its stability to be tested and demonstrated. On 9 June it was flown to Netheravon on Salisbury Plain to visit the RFC's 'Concentration Camp'. Its pilot on this occasion was Maj W S Brancker, who, although he was not an experienced pilot, recorded that, after climbing to 2,000ft and setting course, he was able to make the forty-mile journey without placing his hands on the controls until he was preparing to land. He spent his time writing a report on the countryside passing below, although he did admit to the inclusion of a number of extraneous dots and dashes caused by the more violent bumps or gusts.

This demonstration of the benefits of inherent stability was sufficient to ensure that the B.E.2c was put into production by private constructors to supersede the earlier variants in service with the RFC.

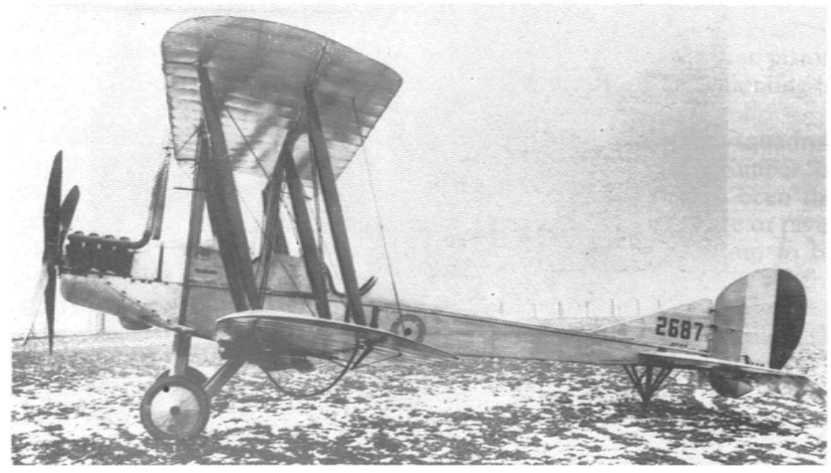


Early B.E.2c 1145 (70hp Renault) after a mishap at RNAS Redcar in October 1916. Note the bomb rack under the sump and the unusual fin marking.
(Capt DS Glover via PHT Green)

Meanwhile, 602 again visited the Concentration Camp on 19 June and stayed there for a week, affording a number of pilots an opportunity to experience its stability at first hand, before returning to Farnborough on the 26th. It was handed over to No 4 Squadron in July, and at the outbreak of war returned to the Aircraft Park, where it was dismantled and crated for shipment to France. When finally reassembled it was erroneously numbered 807, a serial which, it was later realised, duplicated one already issued by the Navy, and it was renumbered 1807. As such it saw service with No 2 Squadron until December, when it returned to England to finish its days in a training unit, being finally struck off charge on 14 December 1915.

Another early variant, 601, was also converted into a B.E.2c. It was fitted with a prototype R.A.F.1a engine, which was dimensionally similar to the Renault but which provided an additional twenty horsepower. On 5 November it caught fire in the air and was completely destroyed, with the tragic loss of its pilot, the aeroplane's designer, Edward Busk.

Although early production B.E.2cs retained the 70hp Renault engine which powered the earlier variants, the Factory's own R.A.F.1a became the standard powerplant as soon as it was available in sufficient numbers. New vertical-discharge exhaust pipes, terminating just above the upper wing centre-section, together with a neat cowling for the engine sump, distinguished the R.A.F.1a-powered examples. A plain vee undercarriage was introduced at the same time, replacing the twin-skid pattern of the earlier machines.



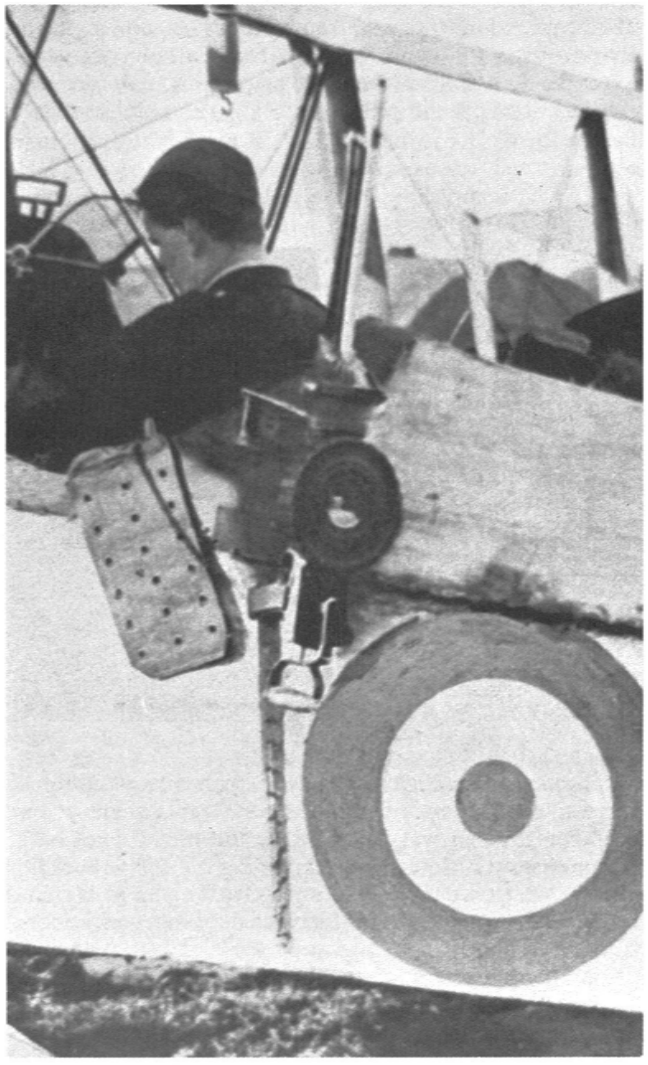
A later B.E.2c, with an R.A.F.1a engine and the vee undercarriage. This particular machine, 2687, was built by Ruston, Proctor, and is fitted with underwing bomb racks.
(via PHT Green)

The first production machine, built by Vickers and given the serial 1748, was delivered to the Aeronautical Inspection Department at Farnborough by 19 December 1914. It was followed by the first Bristol-built example, 1652, on 4 January 1915, this aircraft becoming the first production example to go to France, which it did on 25 January. By the end of March there were twelve in service, and by the end of the year there were more than ten times that number.

The B.E.2c's stability was initially well received by service pilots, and remained so in the less demanding theatres of war, earning the machine such affectionate nicknames as *Stability Jane* or the *Quirk*. One pilot* wrote of it:

* Maj WG Moore, *Early Bird* (Putnam, London, 1963).

But the beauty of these machines was that, once you were up to your cruising height, you could adjust a spring which would hold your elevator roughly in the position you wanted for level flying, and you could afford to ignore totally the violent bumps that threw up one wing-tip and then the other. With your rudder central and held in that position by a spring, you could fly hands-off, because the machine was automatically stable and would right itself whatever position it got into provided there was enough



A B.E.2c, showing the seatbelt (there were no shoulder straps) and defensive armament, a Lewis gun on a swivel mounting.

space between you and the ground. We used to try, when well up, to see if there was any position we could put them in from which they would not right themselves if left alone. If you pulled them up vertically (so that they hung momentarily on the propellers) and then let go everything, they would tail slide very gently and then down would go the nose until the machine gained flying speed and everything would be normal again.

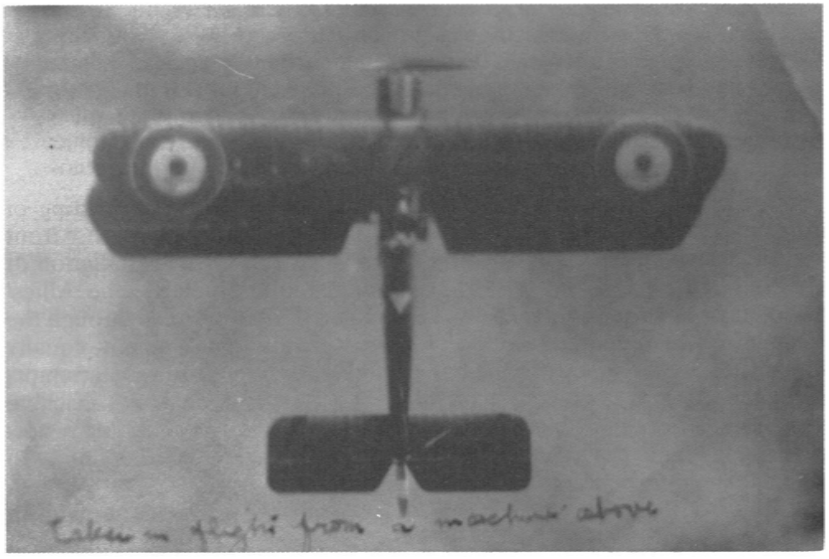
As originally conceived, the B.E.2 was unarmed. When the fitting of armament became desirable, the location of the observer in the front cockpit, which had been done for sound reasons, made the installation of any kind of defensive weaponry almost impossible. Similarly, the Allies' lack of any synchronisation gear, to allow a gun to fire forwards through the propeller disc, rendered the provision of offensive armament equally difficult. However, almost immediately the type entered service attempts were made to arm it, initially with rifles or pistols and later with machine guns, usually the comparatively light, drum-fed Lewis. The rifles and pistols were usually hand held, but the machine guns required a fixed mounting to enable them to be operated with any effect.

At first the necessary mountings were fabricated, *ad hoc*, in squadron workshops, but they gradually became standardised into a number of officially adopted types. The earliest of these appears to have been the 'candlestick' mounting, fixed to the cockpit rim, into which a spike or pivot pin attached to the gun could be inserted. This allowed the gun to be swivelled as necessary to engage the enemy, but relied entirely on the observer's skill in avoiding hitting parts of his own machine. This was superseded by the No 2 Mk 1 mounting designed by Lt Medlicott, and frequently known by his name, in which the gun's pivot pin was placed in a socket which was supported from a tube attached to the front centre-section struts, and arranged to slide up and down. A wire guard was frequently fitted which limited the muzzle movement and prevented the observer from shooting his own propeller.

A 'goalpost' mounting between the cockpits, officially designated the No 10 Mk 1, allowed the observer to fire to the rear, over the pilot's head. This gave some measure of protection against attack, but required courage and co-operation in use because the gun's barrel was barely inches above the pilot's head. It was unusual for a machine to be burdened with the weight of more than one gun, and the observer had to transfer it from mounting to mounting as the need demanded. Wooden racks were often fitted to the fuselage sides, outside the rim of the observer's cockpit, to hold spare ammunition drums.

Another type of mounting, more common to single-seaters, had a Lewis gun fixed to the fuselage side, firing forward at an angle to miss the propeller and with its muzzle held in place by cross-wires. A number of such installations were made on B.E.2cs to satisfy the whim of the more aggressive pilots.

None of these arrangements was entirely satisfactory, and they were far from being universally fitted, so for all practical purposes the B.E.2c remained virtually defenceless. Consequently the advent of true fighter



An unidentified B.E.2c photographed from a machine flying above it. Note the squadron marking on the rear decking behind the pilot's cockpit.

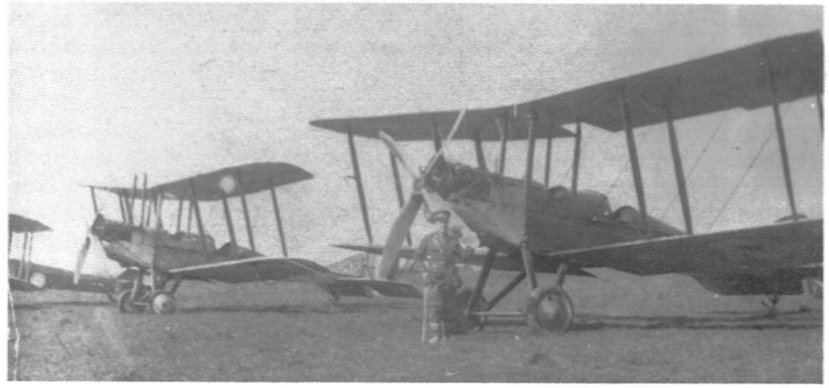
aeroplanes, such as the Fokker monoplanes of 1915 and the Albatros biplanes which followed them, meant that the B.E.2c became easy prey, along with its equally unarmed contemporaries. Thus Noel Pemberton Billing was able to shock Parliament, and the nation, with his accusations of incompetence and murder, and so indirectly bring to an end the family of Royal Aircraft Factory aeroplanes.

A Bristol-built B.E.2c armoured with over 400lb of steel plate to protect the engine and crew against ground fire.

A few machines were also fitted with bomb racks, either under the wings to carry four 20lb bombs, or under the fuselage, at the centre of gravity, where one 112lb bomb was the normal load.

Losses to ground fire, as the B.E.s monotonously patrolled over the trenches on reconnaissance or artillery observation duties, were also a problem and, in an attempt to provide a solution, a small number of machines were fitted with armour plate which covered the forward fuselage. While this effectively protected the engine, fuel tank and crew against small-arms fire, the reduction in streamlining, together with the addition of over 400lb in weight, so reduced performance that the idea was shortlived.

In common with its predecessors the B.E.2c was used by the Factory as a test bed for a wide range of aeronautical experiments and investigations, a purpose for which its stability and entirely predictable performance made it ideal. The machines used in such experiments were not built at Farnborough, but were standard production machines, built by private contractors and modified as required after inspection.



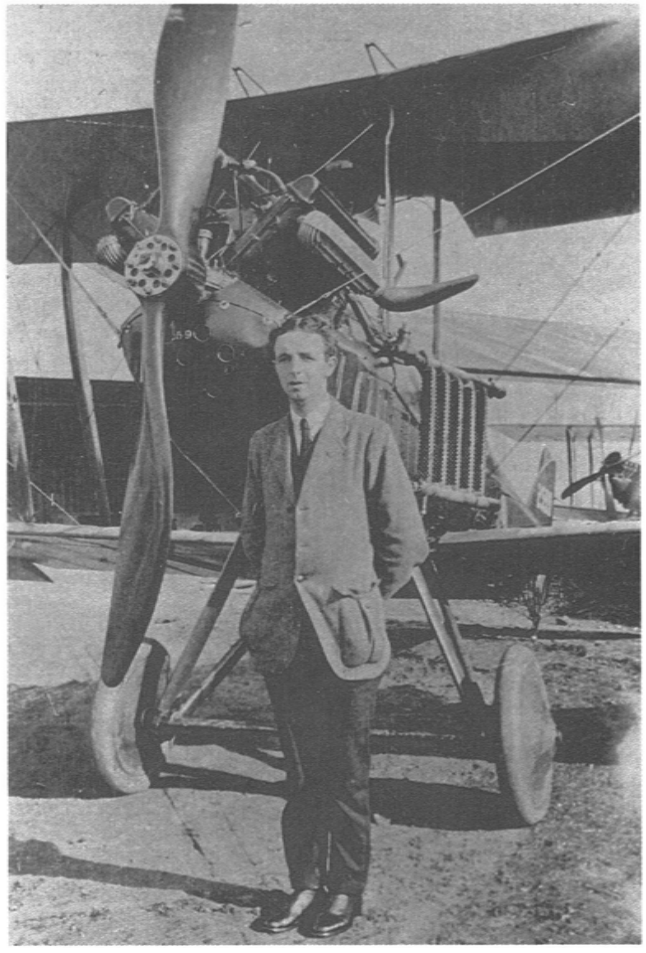
B.E.2cs at South Carlton in 1917. The aircraft nearest to the camera has had its exhausts modified to discharge to the side instead of over the upper wing, as was usual for machines powered by the R.A.F.1a.
(via PHT Green)

An oleo undercarriage incorporating a small buffer-type nosewheel was fitted to a few B.E.2cs, but any improvement in landing, and in handling on the ground, could not compensate for the reduction in performance caused by the increased weight and considerable drag, and it was not adopted for general use.

Another undercarriage experiment, which was conducted at the School of Aerial Gunnery, Loch Doon, in November 1916, comprised the removal of the wheels of 4721, an early Vickers-built machine, and the substitution of a central float manufactured by S E Saunders. This was simply attached to the undercarriage skids, and a small tail float was also fitted. Neither the intention nor result of this experiment are now recorded, but it is doubtful whether it served any useful purpose.

Like most other aeroplanes which had a lengthy service career, the B.E.2c was constantly modified and improved with a view either to simplified production or improved performance. It was with the latter object in mind that the wing section was changed early in 1916 from R.A.F.6 to R.A.F.14, with a consequent slight improvement in rate of climb.

As its performance became the subject of growing criticism, several attempts were made to re-engine the B.E.2c with the 150hp Hispano-Suiza,



A B.E.2c fitted with a 150hp Hispano-Suiza engine. The identity of the gentleman standing in front of it is now known, but, judging by his worried look, he may have been responsible for this remarkably ugly installation.
(JM Bruce/GS Leslie)

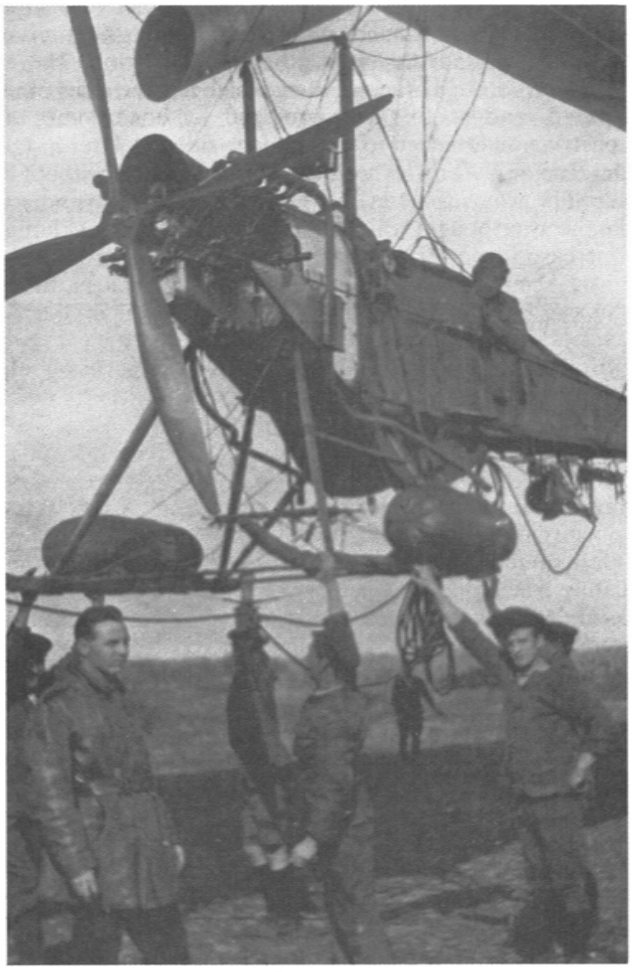
this having been the first projected use for this impressive new engine. The first attempt managed to produce one of the ugliest installations of this neat and attractive powerplant that it is possible to imagine. The engine was partially enclosed within a crude cowling which left the sides of the cylinder blocks exposed, and cooling was provided by honeycomb radiators of unusual construction attached to the fuselage sides. A later installation was made in the Bristol-built machine 2599. This was neater without being neat, for the radiators, which this time were fitted above the cylinder heads, still looked like the afterthought which, in reality, they were. Although the sixty per cent increase in power obviously improved the aeroplane's performance, it was then decided to develop new machines to realise the Hispano-Suiza's full potential, and the plan to fit it in the B.E.2c was discontinued.

For some obscure reason the R.A.F.1a engine was never popular with the RNAS, so some of the few B.E.2cs operated by that service were equipped either with the six-cylinder 75hp Rolls-Royce Hawk or the 90hp Curtiss OX-5, a car-type radiator being used in each case. It seems strange that this simple solution to engine cooling appears not to have been considered by those responsible for the experimental Hispano-Suiza installations.

When nocturnal bombing raids on London and the eastern counties by the huge German rigid airships brought the war to civilians for the first time, it immediately became apparent that some defensive action was urgently needed, as much to preserve the nation's morale as to prevent the relatively small amount of damage that was being suffered. Here the stable B.E.2c came into its own, for, being easy to fly and to land, it made an admirable night-fighter. However, like most contemporary aeroplanes, it lacked the performance to attack the enemy airships under any but the most favourable circumstances. Whilst they were slower, the airships could better any aeroplane's ceiling, and could ascend at an incredible rate simply by releasing large quantities of ballast. In a commendable attempt to overcome the poor climb and endurance of the B.E.2c compared with that of its intended victim, an experiment was made in 1915 in which the aeroplane was suspended from the envelope of a type SS non-rigid airship. It was intended that the 'airship-plane' would patrol at height until the raiders approached, when the aeroplane would detach itself from the envelope and go into the attack. The experiment was discontinued after 21 February 1916, when a fatal accident occurred after the aeroplane failed to release properly.

This was not the only connection between the B.E.2c and the Submarine Scout airship, for the S.S.1 class consisted of a Willows-type envelope from which was suspended an aeroplane fuselage, the early B.E.2c being one of three types used, complete with engine, propeller and undercarriage skids. No wheels were needed, because ascents and landings were made without forward motion.

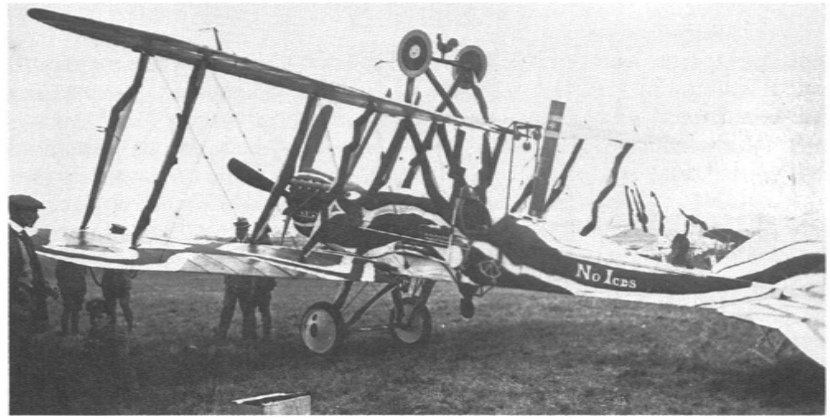
On the night of 2 September 1916 the Schütte-Lanz airship SL11 was spectacularly brought down over Cuffley in Hertfordshire by Lt William Leefe Robinson of No 39 Squadron RFC, flying B.E.2c No 2092, an act for which he was awarded the Victoria Cross. This was not the first time that an



A Renault-powered B.E.2c fuselage in use as a car for an SS-class airship. Note the flotation bags attached to the undercarriage skids, the additional fuel tank beneath the fuselage, and the air duct to the ballonet.

enemy airship had been brought down, for Flt Sub-Lt Rex Warneford had brought down the Zeppelin L37 with a bomb more than a year previously, but it was certainly the most public instance. Warneford's action had taken place over the Belgian coast, whereas Leefe Robinson's victim fell in flames where most of the population of London could see it. Before the end of the year four more raiders, the Zeppelins L21, L31, L32, and L34, had fallen to the guns of night-flying B.E.2cs.

The B.E.2c remained in service, in declining numbers, until the end of

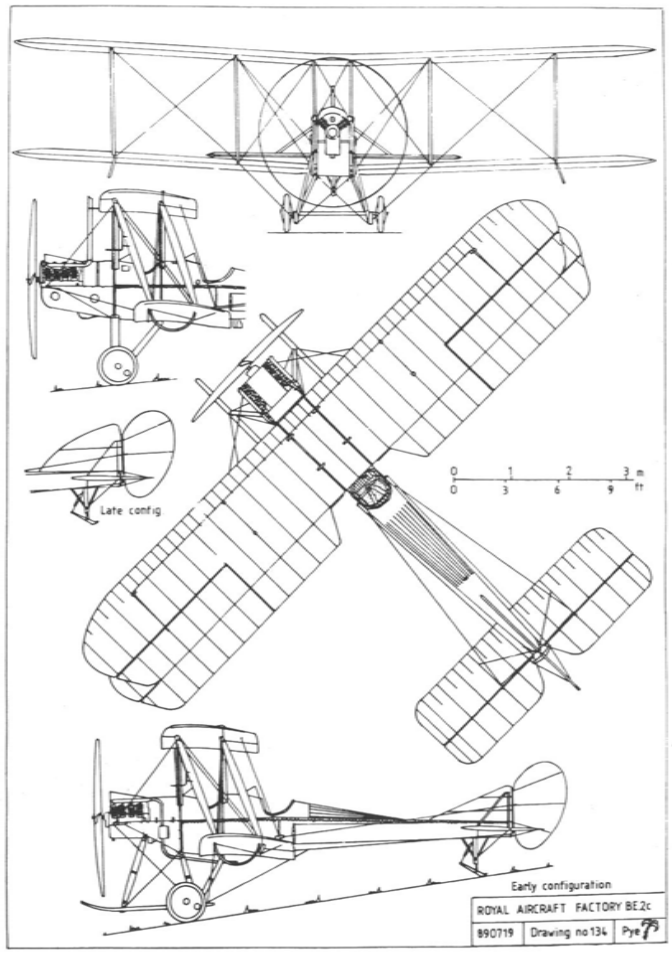


The 'B.E.2xyz' was a heavily modified B.E.2c which took part in a post-war Hendon pageant. In addition to the extra undercarriage for 'inverted landings', it appears to have been rigged with negative stagger, and was almost certainly not capable of safe flight in this form.

the war, gradually being superseded by later variants and by newer designs. It saw service with more than a dozen squadrons of the RFC in France, in Home Defence units and training establishments, with the RNAS, and in every theatre of war, including Africa and the Middle East. At one time it was certainly the most efficient and the most numerous aeroplane in use by the British armed forces. That it was allowed to outlive its usefulness was a tragedy that should be blamed upon those who were responsible for its procurement, not upon the machine or its designers.

The B.E.2c did not survive in service use for very long after the Armistice. At least one was retained as a test vehicle at Farnborough until the mid 1920s, and a small number found their way on to the civil register via the numerous disposal sales held after the war's end. Three examples survive in museums.

Powerplant:	70hp Renault V-8; 90hp R.A.F.1a V-8
Dimensions:	
span	37ft 0in;
chord	5ft 6in;
gap	6ft 3in;
stagger	2ft 0in;
dihedral	3½°;
incidence	3½° (R.A.F.6); 4° 9″ (R.A.F.14);
wing area	354 sq ft;
length	27ft 3in;
height	11ft 1½in;
wheel track	5ft 9¾in.

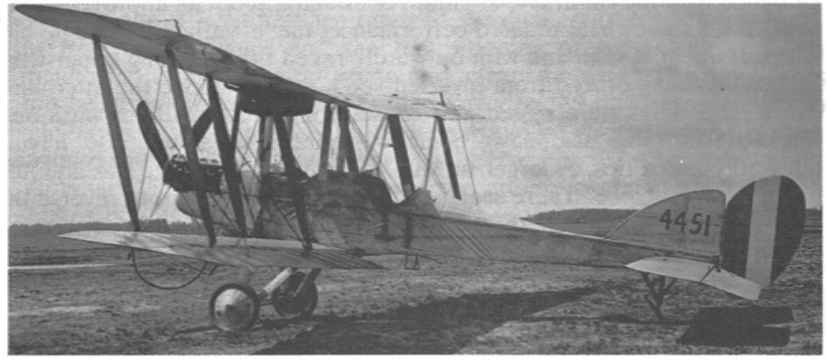


Weights:
(R.A.F.1a): 1,370lb (empty);
2,142lb (loaded).

Performance:
(R.A.F.1a):
max speed 86mph at sea level;
72mph at 6,500ft;
ceiling: 10,000ft;
endurance 3¼hrs;
climb 6min to 3,000ft;
20min to 6,500ft.

B.E.2d

Although it was structurally similar to the B.E.2c, this new variant included dual controls, presumably to give the observer a chance of survival if the pilot was hit. The provision of controls in the front cockpit necessitated the elimination of the fuel tank which was previously installed under the observer's seat, to allow the rudder cables and the torque tube linking the two control columns to pass through this space. A large gravity tank was substituted, positioned beneath the upper port wing near its root, and was connected to an additional gravity tank within the fuselage top-decking, between the cockpits. At the same time the capacity of the pressure tank, located immediately behind the engine, was increased from fourteen to nineteen gallons. Thus the B.E.2d had a total fuel capacity of forty-one gallons, compared with the thirty-two gallons of the B.E.2c, giving it a useful increase in endurance, albeit at the expense of a reduction in the type's already leisurely rate of climb.



B.E.2d 4451. Note the gravity tank under the upper port wing. As was common with later examples of the type, this machine has been fitted with the larger, B.E.2e-type fin.
(JM Bruce/GS Leslie)

Production orders for the B.E.2d were placed in October 1915, and it was built in relatively small numbers by the British and Colonial Aeroplane Company, Ruston Proctor, and Vulcan. Such great things were expected of the later 'e' variant that all unfulfilled orders for earlier models were changed to the latter type, and consequently many machines which began as B.E.2ds were actually delivered as B.E.2es.

Use of the B.E.2d was largely confined to training establishments, where its dual controls were a boon, its endurance allowed the best use to be made of favourable weather, and its outdated performance was no real handicap.

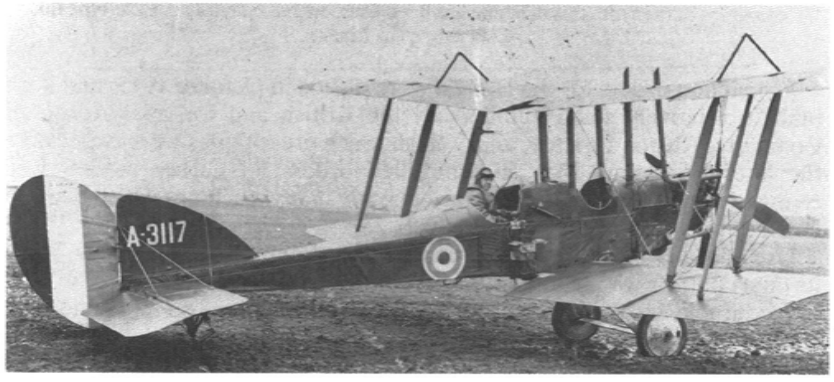
Powerplant: 90hp R.A.F.1a V-8
Dimensions:
span 36ft 10in;
chord 5ft 6in;

gap	6ft 3in;
wing area	354 sq ft;
stagger	2ft 0in;
dihedral	3½°;
incidence	4° 9″;
length	27ft 3in;
height	11ft 0in.
Performance:	
max speed	88mph at sea level;
	75mph at 6,500ft;
ceiling	7,000ft;
climb	12min to 3,000ft;
	36min to 6,500ft.

B.E.2e, f, & g

Designed with the admirable intention of bringing about an improvement in the B.E.2's somewhat outdated performance, the 'e' variant had single-bay wings of unequal span and with outwardly-raked tips, the long upper-wing extensions being braced from inverted-vee kingposts above the interplane struts. The wings were rigged at a constant incidence, without wash-out. The tailplane was also new, being of reduced area and also having outwardly-raked tips. A larger fin with a curved leading edge was adopted for the new machine. There seems to have been no attempt to reverse the crew positions, although the arrangement of the fuel tanks was again revised.

The prototype, which was created by fitting the new wings and tail surfaces to Bristol-built production B.E.2c number 4111, made its first flight on 18 February 1916. As had been expected, its performance was somewhat better than that of earlier variants, and on 1 March Mervyn O'Gorman

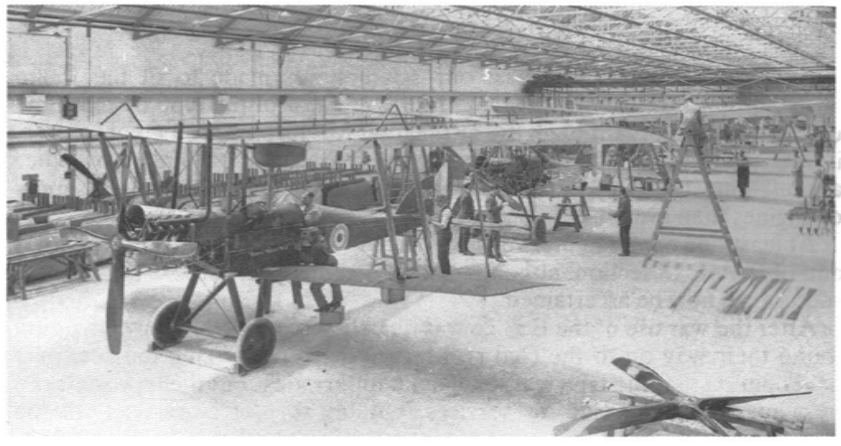


B.E.2e A3117 with a camera fitted beside the pilot's cockpit. The type's inherent stability must have been an asset when plates had to be changed while trying to hold the machine in straight and level flight.

informed the War Office that its maximum speed was 97mph at ground level and about 90mph at 6,000ft. There is some reason to believe that these results may have been obtained using the R.A.F.1b engine, which was rated at 105hp, but this engine did not enter production, and the 90hp R.A.F.1a remained the standard powerplant. Thus powered, the B.E.2e's speed was recorded as 82mph at 6,000ft, which, although not fast, was at least ten per cent faster than the B.E.2c at the same altitude.

Lateral control was reported as being 'very much better', landing was 'more easy', and climb increased by between seven and ten per cent. These improvements were considered sufficient to justify putting the B.E.2e into large-scale production, and also having all unfulfilled orders for earlier variants completed as B.E.2es. While these machines were all taken on charge by the Royal Flying Corps as B.E.2es, however, it was found that, in practice, they were of three distinct and different types: the B.E.2e as designed, the B.E.2c fuselage fitted with the new tail and single-bay wings, and the B.E.2d fuselage similarly equipped. Each type had a different arrangement of fuel tanks and a slightly different performance. In addition, those with the B.E.2d fuselage retained the dual controls of that variant. This made maintenance and the requisitioning of spares unnecessarily difficult, and clearly required some easy means by which the three types could be distinguished. The RFC therefore decided that aeroplanes with single-bay wings and the B.E.2c fuselage would be designated the B.E.2f, and those with the B.E.2d fuselage would be B.E.2gs.

Although the B.E.2e's performance was an improvement on that of its predecessors, it was less than adequate for service on the Western Front and, since the machine was as poorly armed as previous variants, losses were high. Nonetheless, the B.E.2e carried on to the end of the war,

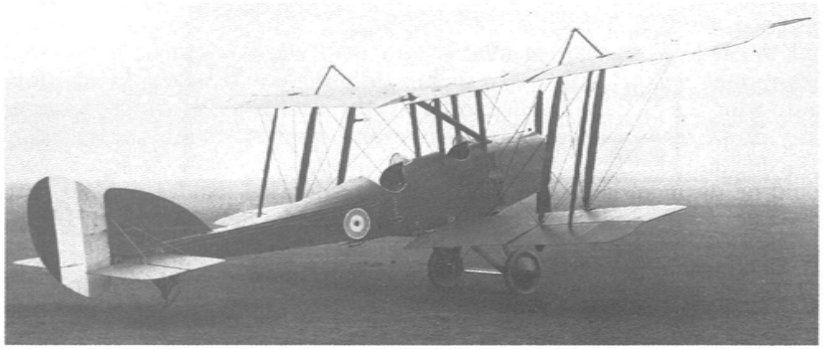


B.E.2gs under construction at Wolseley Motors. The nearest aircraft is A3113, a presentation machine bearing the legend *Orissa States No3*.
(via PHT Green)

gradually being replaced by the R.E.8 and various other, more modern, types.

The B.E.2e also served in every other theatre of war and, by the time of the Armistice, when all outstanding orders were cancelled, it had been produced in greater numbers than any other B.E.2 variant. In addition, a very great number served in training establishments in England, and it was rare indeed for any pilot to gain his wings without having flown one.

Allegations that the long extensions on the upper wing were structurally unsound, and that they would collapse if too much stress was put on them by violent manoeuvres, were investigated by the Royal Aircraft Factory and proved to be unfounded. Despite this the rumours persisted, and prompted a number of pilots to treat their mounts with undue caution.



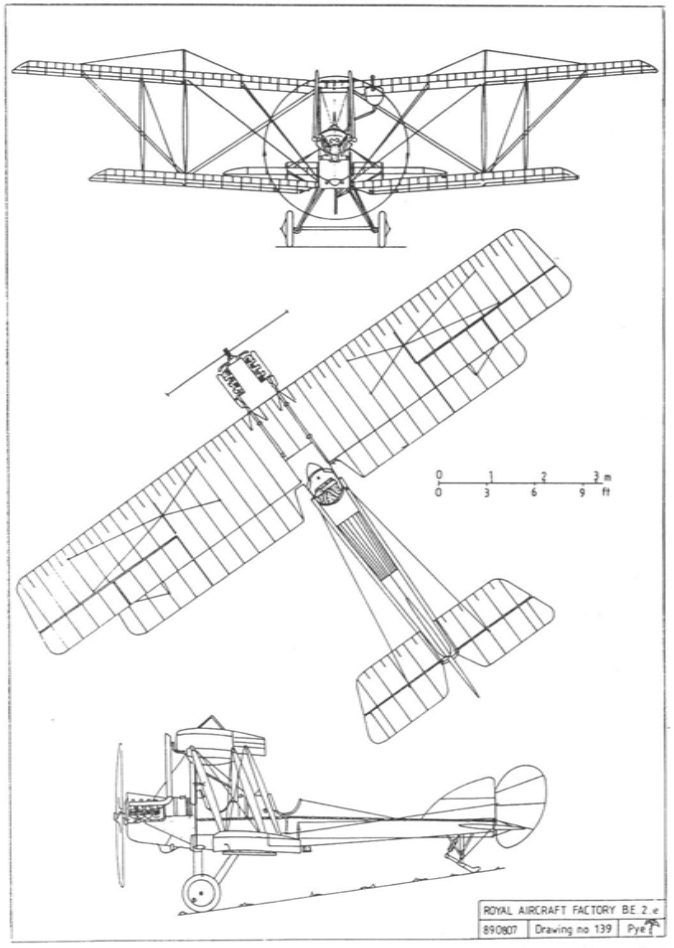
RNAS B.E.2c 6326 with a neatly-cowled Curtiss OX-5 engine and a car-type frontal radiator.

As with the B.E.2c, at least one attempt was made to fit the 150hp Hispano-Suiza, utilising a car-type frontal radiator of the type by that time used on the S.E.5. Although the installation was technically a great success, it was not adopted for production, simply because a number of other aircraft—most notably the S.E.5—had a better claim to the limited supply of engines then available.

At least one experimental version was built with wings of increased chord and of R.A.F.18 section, although neither its intended purpose nor relative success can now be ascertained.

After the war use of the B.E.2e was quickly discontinued. Only a handful found their way on to the civil register, perhaps reinforcing the generally held opinion that the type was staid and uninteresting, but the type was used by a number of foreign air services, notably that of Norway, until the mid-1920s.

Powerplant:	90hp R.A.F.1a V-8 105hp R.A.F.1b V-8



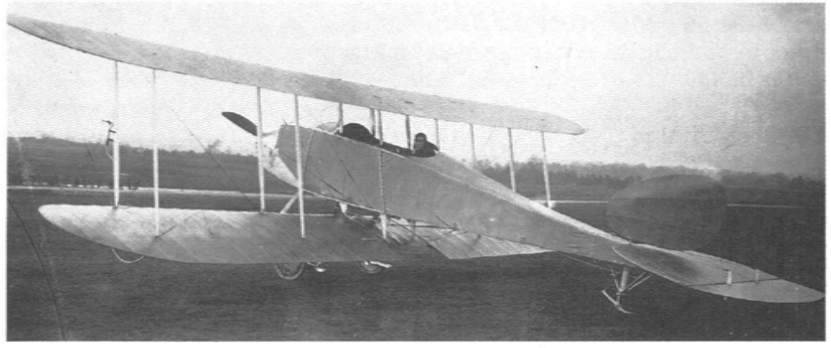
Dimensions:	
span	40ft 6in (upper); 30ft 6in (lower);
chord	5ft 6in;
gap	6ft 3in;
wing area	360 sq ft;
stagger	2ft 0in;
dihedral	3½°;
incidence	4° 9″;
length	27ft 3in;
height	11ft 9in.
Weights:	1,431lb (empty); 2,100lb (loaded).

Performance (R.A.F.1a):	
max speed	90mph at sea level; 82mph at 6,500ft;
ceiling	9,000ft;
climb	20min to 6,000ft;
endurance	4hrs.
(R.A.F.1b)	
max. speed	97mph at sea level;
ceiling	12,000ft.

B.E.3

The third in the Factory's series of tractor designs, the B.E.3 was originally conceived as being essentially similar to the B.E.1/2 but powered by a rotary engine, to enable its performance to be compared with that of the stationary-engined aircraft. However, the final design, for which John Kenworthy was responsible, differed quite considerably in detail. Its two-bay wings inherited their construction and planform from the previous design, and retained warping for lateral control, but were heavily staggered. The tailplane was similar to that of earlier B.E.s but the rudder, while very similar in shape, was mounted with its shorter axis vertical and with a small area forward of its steel-tube pivot to provide an aerodynamic balance. This enabled an undivided elevator to be fitted. The fuselage was broader than in previous models, the increase being necessitated by the diameter of the rotary engine, and was mounted clear of the lower wing in the mid-gap position. As in the predecessors, the undercarriage incorporated lengthy skids, but was simplified by the elimination of a strut on each side.

A Paulhan Biplane, serial F2, of unusual and not entirely successful design, had been sent to the Army Aircraft Factory by the Air Battalion in February 1912, presumably for repair. Yet again O'Gorman sought



The B.E.3 with Geoffrey de Havilland in the cockpit.
(Military Aircraft Photographs)

permission to reconstruct the machine along more conventional lines. Such permission was readily granted but, as before, only its engine, a 50hp Gnome, was actually used in the new aeroplane. An alternative and unconventional control system, in which the warping mechanism for lateral control was operated by the pilot's feet, was fitted for a brief period but removed again before its effectiveness could be fully evaluated because, for some reason which is not now apparent, the machine was urgently needed by the RFC.

The B.E.3 made its first flight on Friday 3 May 1912, with Geoffrey de Havilland, at that time the Factory's only test pilot, at the controls. Later the same day, as was then common practice, he took up several passengers, including Factory personnel and members of the recently formed Royal Flying Corps.

On the following Monday de Havilland took the B.E.3 up again, the rudder having been adjusted to increase the available movement and the wings re-rigged to increase the amount of wash-out. Although he reported that it was now 'flying better', he broke two undercarriage struts and the propeller in a heavy landing. By 10th May the damage had been repaired, the skids being replaced and the front undercarriage struts moved slightly to the rear in an effort to strengthen the assembly and prevent a recurrence of the damage.

These modifications were clearly considered satisfactory, as on the following Monday, 13 May 1912, the B.E.3 was handed over to the RFC. That only ten days had elapsed since its first flight might be taken as confirmation that it was wanted in a hurry. It was given the serial 203, together with the nickname *Goldfish*, and served with No 3 Squadron until early in 1914, occasionally returning to the Factory for minor repairs.

The B.E.3 took part in a wide range of signalling experiments, not only

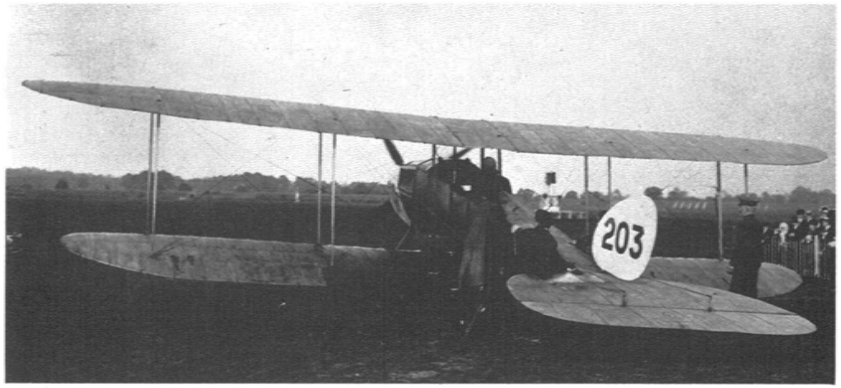
The B.E.3 after hand-over to the RFC, most probably at Hendon in September 1913.
(Military Aircraft Photographs)

B.E.3 number 203 with four-bladed propeller, date and location unknown.
(Military Aircraft Photographs)

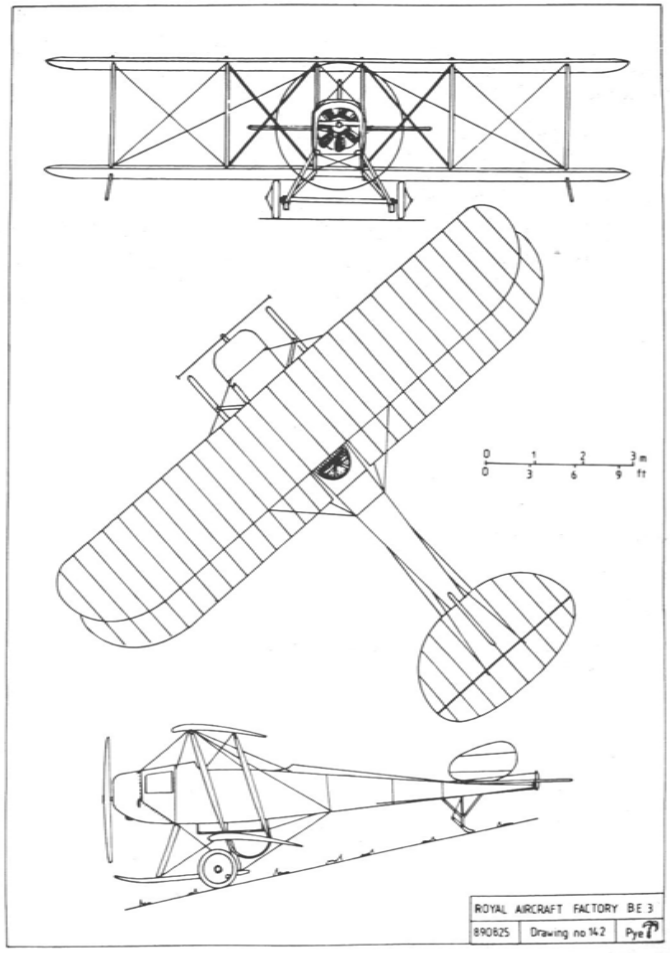
with wireless, but with electric lamps and flags. At some stage it was fitted with an experimental four-bladed propeller with alternate acute and obtuse angles between the blades.

Following the crash of its sister aircraft, the B.E.4, in March 1914, which was believed to have been caused by the rudder post breaking, the B.E.3 was fitted with new vertical tail surfaces. These comprised a B.E.1/2-type rudder mounted above the fuselage, so as to be clear of the undivided elevator, and hinged behind a new triangular fin, the whole design being clearly inspired by the tail of the H.R.E.2.

The B.E.3's flying career ended soon after it received its new fin and rudder, and it became a ground instructional airframe. It was last recorded at Farnborough at the end of 1914 but, like many other early aeroplanes, its eventual fate is not known.



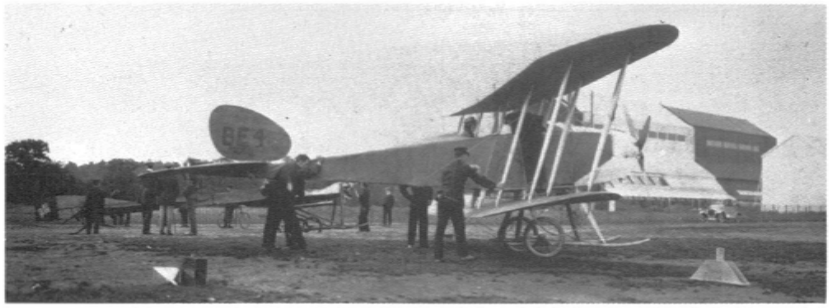
B.E.3 number 203 at Hendon after handover to the RFC.
(JM Bruce/GS Leslie)



Powerplant: 50hp Gnome rotary.
Dimensions:
span 39ft 6in;
chord 5ft 6in;
length 27ft 3in.

B.E.4

Structurally identical to the B.E.3, the fourth aeroplane in the Factory's tractor series was alleged to be a 'reconstruction' of Bristol Boxkite number F9, which at least provided the new machine with its 50hp Gnome rotary. The B.E.4 was test-flown by Geoffrey de Havilland on 24 June 1912 and,



A B.E.4 on Farnborough Common with the Factory buildings, including the newly extended airship shed, in the background.
(JM Bruce/GS Leslie)

following the usual brief period of trials and adjustments, was handed over to the Royal Flying Corps on 8 August. After a short period with the designation 'B.E.4' on its rudder, it was given the serial 204.

An engine failure brought about a forced landing which caused some damage, and 204 was returned to the Factory at the beginning of September for repairs. While there, its previously hardworked engine was replaced by a new Gnome, this time of 70hp.

Two other examples, serials 416 and 417, are known to have been built by private contractor, at least one being fitted with dual controls for use at the Central Flying School (CFS). It is possible that a further example was also built and was given the serial 303.

On 11 March 1914 204 crashed on Salisbury Plain with the tragic death of its crew. The subsequent enquiry offered the opinion that the rudder shaft had become crystallized and had snapped, one of the first suggestions of metal fatigue. While this could not be conclusively proved, it raised sufficient doubt regarding the safety of the B.E.3/4 rudder for a new unit to

A B.E.4 prepares to take off, observed by a group of senior officers, one of whom appears to be HM King George V.
(JM Bruce/GS Leslie)

be developed and fitted to the remaining machines with commendable rapidity. The new unit comprised a B.E.2-type rudder mounted above the undivided elevator and behind a triangular fin, its obvious origins in the H.R.E.2 clearly accounting for the speed with which it was designed. Thus equipped, 416 and 417 continued to serve at the CFS, and are believed to have ended their respective careers in the almost inevitable training crashes.

Powerplant:	50hp Gnome rotary 70hp Gnome rotary
Dimensions:	
span	39ft 6in;
chord	5ft 6in;
length	27ft 3in.

B.E.5

The fifth of the Royal Aircraft Factory's series of two-seat general-purpose tractor biplanes returned to the B.E.1/2 layout, but used a 60hp ENV 'F' engine recovered from the damaged Howard Wright biplane of which it was ostensibly a 'reconstruction'. Being a water-cooled engine, the ENV obviously needed a radiator, and this was mounted on the forward centre-section struts in a manner similar to that on the B.E.1.

The B.E.5's first flight was made on 27 June 1912, only three days after that of the B.E.4, and it was handed over to the RFC on 18 July. It served with No 2 (Aeroplane) Squadron for a few weeks before returning to the Factory to be re-engined with a V-8 Renault. It thus became, in effect, a standard B.E.2, and was thereafter regarded as such in service. After being returned to the RFC it served briefly with No 3 Squadron before returning to No 2, and was allotted the serial 205.

B.E.5 number 205 at Montrose, after the engine change which brought it to B.E.2 configuration.
(via J Prendagast)

On 27 May 1913 the starboard upper wing collapsed while the aircraft was making a gliding turn at a height of about 2,500ft, and the pilot, Lt Desmond Arthur, was thrown out and killed. An investigation conducted by the Royal Aero Club's Accident Investigation Committee concluded that the cause of the disaster was a badly spliced repair near the tip of the rear spar, although there was no record of the repair being made either by the Royal Aircraft Factory or while the machine was in service. In addition to prompting the suggestion that all such repairs should be properly inspected and the name of those carrying out the work recorded, the incident triggered another attack on the Royal Aircraft Factory by C G Grey in the pages of *The Aeroplane*. The machine was officially struck off charge on 25 September 1915.

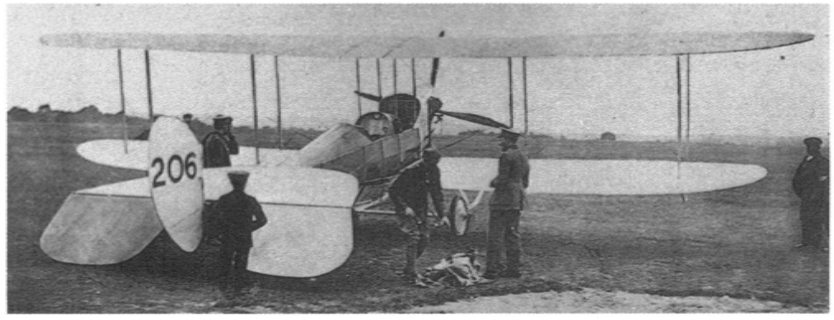
Data as B.E.2.

B.E.6

Officially a 'reconstruction' of the ill-fated S.E.1, and powered by its 60hp ENV engine, the B.E.6 was identical to the B.E.5 and was built at the same time, its designation being intended not to distinguish it as a separate type, but merely to identify it as the sixth in the B.E. series of tractor machines.

The ENV engine may have sustained more damage in the crash of the S.E.1 than had been realised, for the B.E.6 did not make its first flight until 5 September 1912, some months after its sister. While it is not recorded how it was powered on that occasion, it was fitted with a 60hp Renault when it was handed over to the RFC a few days later, and it is probable that the ENV was never actually used.

The B.E.6 was given the serial 206, and seems never to have been regarded as anything other than a standard B.E.2, which, with its Renault engine, is effectively what it was. By September 1914 it had flown a total of 111 hours and, following a period with No 2 Squadron, it had been



B.E.6 number 206 soon came to be regarded as a B.E.2 which, in effect, is what it always was.
(JM Bruce/GS Leslie)

transferred first to No 4 Squadron and then to No 6, with whom it saw active service in France before being relegated to training duties back in England.

Some time during 1914 it underwent an engine change, the replacement being the 70hp Renault that was, at that time, the standard power unit for the B.E.2. Its further career and eventual fate have not been discovered.

Data as B.E.2.

B.E.7

Designed by John Kenworthy about July 1912, the B.E.7 was, essentially, a high-powered version of the B.E.3/4. It used the same wings and tail surfaces as the earlier types, but had its forward fuselage shortened by one bay to compensate for the increased weight of the 140hp two-row Gnome rotary selected as its powerplant. The undercarriage was also similar to that of the B.E.3/4, but with the skids suitably shortened to match the new fuselage.

Construction was completed early in 1913, the first flight taking place on 28 February with Geoffrey de Havilland at the controls. It was apparently judged to be faultless as built, for it was handed over to the Royal Flying Corps later the same day.

The B.E.7 was given the serial 438, although there is some evidence to suggest that it bore the number 408 for a brief initial period. This may have been due to a simple error, as that identity had been given to a Bristol Boxkite. Alternatively, it is possible that it was done deliberately to create the impression that the B.E.7 was a reconstruction of the Bristol, which had been grounded late the previous year.

On 2 May the B.E.7 achieved an altitude of 8,400ft piloted by Maj Gerrard, who was accompanied by two air mechanics who shared the forward cockpit, thus establishing a new British record.

The B.E.7 continued to serve at the Central Flying School, where it was regarded as 'very satisfactory', until November 1913, with a brief visit to the Factory in June, presumably for repairs. It was struck off charge when it was discovered that flames from the engine exhaust ports had burnt, and seriously weakened, the engine bearers.

Powerplant:	140hp two-row Gnome rotary.
Dimensions:	
span	39ft 6in;
chord	5ft 6in;
length	27ft 3in

B.E.8

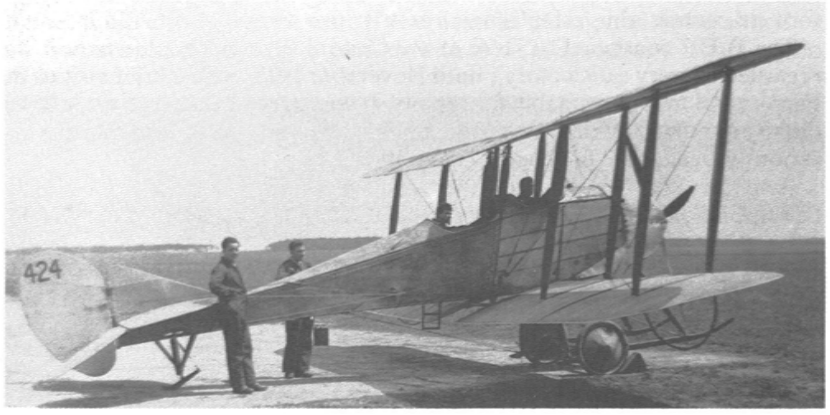
The rotary-engined B.E.8 was designed by John Kenworthy. It broadly followed the layout of his previous designs, the B.E.3 and B.E.4, but its

lower wings were attached directly to the fuselage, without the gap of the earlier designs, and the tail surfaces were modelled upon those of the original B.E.2. In common with most of its contemporary stablemates, the B.E.8 had wing-warping for lateral control and undercarriage skids to protect the propeller tips during landing.

The prototype B.E.8, with undivided cockpits.
(Military Aircraft Photographs)

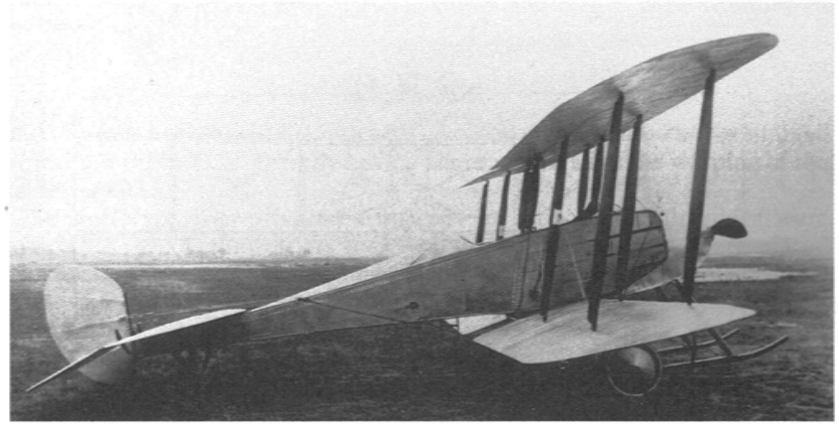
The prototype, which was powered by a 70hp Gnome and had no division between the cockpits, made its first flight on 20 August 1913. It was followed by a second example which had obviously been built concurrently, as it flew less than three weeks later, on 8 September.

The type was apparently thought to present a viable alternative to the B.E.2, and was adopted for limited production by Vickers, which built



A production standard B.E.8, built at Farnborough, with a triangular fin, divided cockpits, and an 80hp Gnome engine.
(via Tim Mason)

eleven, the Coventry Ordnance Works (seven), and the Bristol based British and Colonial Aeroplane Company (six), the initial order being placed with the last-named company a few days before the prototype first flew. Production examples differed from the prototypes in having a decking between the cockpits and a triangular fin identical to that later adopted for the B.E.2c. They were powered by 80hp Gnome rotary engines driving four-bladed propellers. The two prototypes were later converted to production standard and transferred to the RFC, in whose service they bore the serials 423 and 424.



Another view of the prototype B.E.8. The family resemblance to the B.E.2 is obvious.

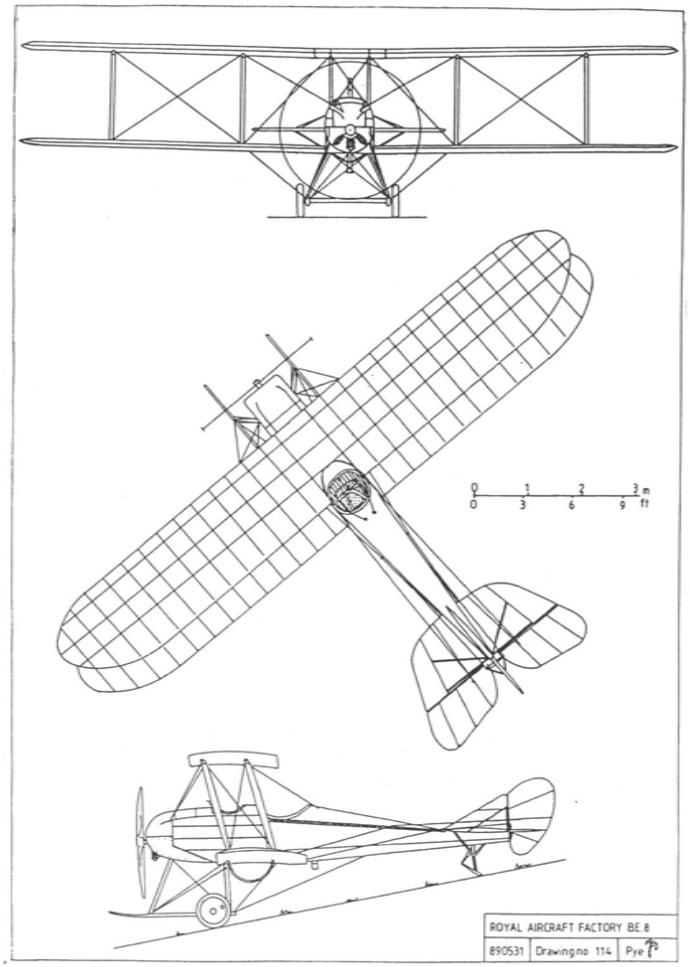
The first production machine, 365, was delivered for inspection on 10 March 1914 and was retained at the Royal Aircraft Factory. Records indicate that it was eventually tested to destruction.

Nicknamed *The Bloater*, the B.E.8 served in small numbers with Nos 1, 3, 5, 6 and 7 squadrons of the RFC and at the Central Flying School, and two examples found their way to India. The type saw service on the Western Front in the early days of the war, but was regarded as being somewhat underpowered. Unfortunately it proved to be rather prone to spinning, and as that manoeuvre and the recovery from it were far from universally understood, several machines were lost in crashes. On 18 August 1914 391 crashed at Peronne, killing its observer and badly injuring the pilot, Lt R Smith-Barry. He eventually recovered, although he needed to walk with a stick for the rest of his life, and in 1917 founded and commanded the School of Special Flying at Gosport, in Hampshire.

The B.E.8's fuel system appears to have been a source of annoyance and the subject of criticism since, if the need arose to repressurise the tank manually, the hand pump was in the observer's cockpit and the pressure gauge was in the pilot's. Difficulty in communication could result in fuel overflowing, with the obvious fire risk. Although there is no evidence of such a fire actually occurring, the problem clearly reduced the crews'

confidence in their mounts.

In January 1915 an attempt was made to improve the B.E.8's performance by the substitution of a 100hp Monosoupape for the 80hp engine. The conversion was made to 658 but, while it had the desired effect, the 'Mono' was relatively scarce, those available being needed for more potent aeroplanes, so no service B.E.8s were ever thus powered. So, underpowered, yet denied the proven remedy, the remaining B.E.8s had all been withdrawn from front-line service by mid 1915, and finished their careers with training units.



Powerplant:	80hp Gnome rotary
Dimensions:	
span	37ft 8in;
chord	5ft 6in;
gap	6ft 0in;
wing area	368 sq ft;
length	27ft 4½in;
height	9ft 4in.
Performance:	
max speed	70mph at sea level;
climb	10½min to 3,000ft;
endurance	1½hrs.

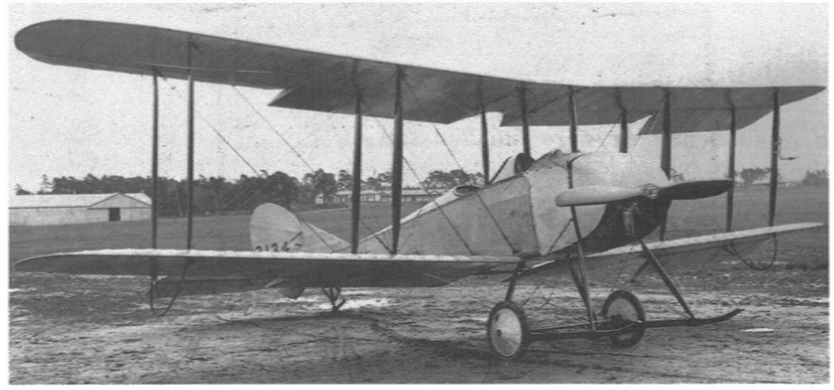
B.E.8a

Making its debut early in 1915, the B.E.8a used the wings and horizontal tail surfaces of the B.E.2c, thereby having ailerons instead of the warping of the earlier model.

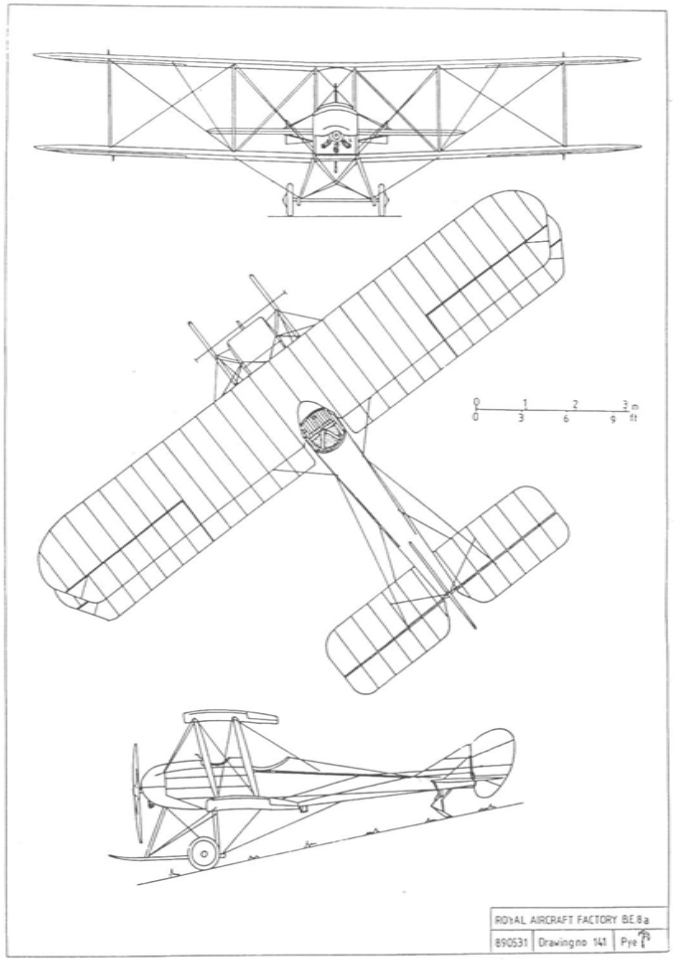
No prototype was produced. Instead, as soon as the drawings were completed, production orders for twenty-one machines each were placed with Vickers and the Coventry Ordnance Works. The 80hp Gnome, as used in the B.E.8, remained the standard engine, although a few machines were fitted with the Clerget 7Z of similar power.

One example was used to test the experimental 120hp R.A.F.2 radial engine, and another had its undercarriage modified to incorporate skis affixed to the axle inboard of the wheels, but neither installation was adopted for production machines.

With a perception that was all too rare at that stage in the war, the RFC never regarded the B.E.8a as an operational machine, and the majority served with reserve squadrons and other training units in the UK. It seems to have shared the earlier version's reputation for being easy to spin, and as



Vickers-built B.E.8a 2134, showing its B.E.2c-type wings, incorporating the ailerons which distinguished the type.



a result a number were fitted in service with the larger fin, with its distinctive curved leading edge, which was the standard fitment for the B.E.2e.

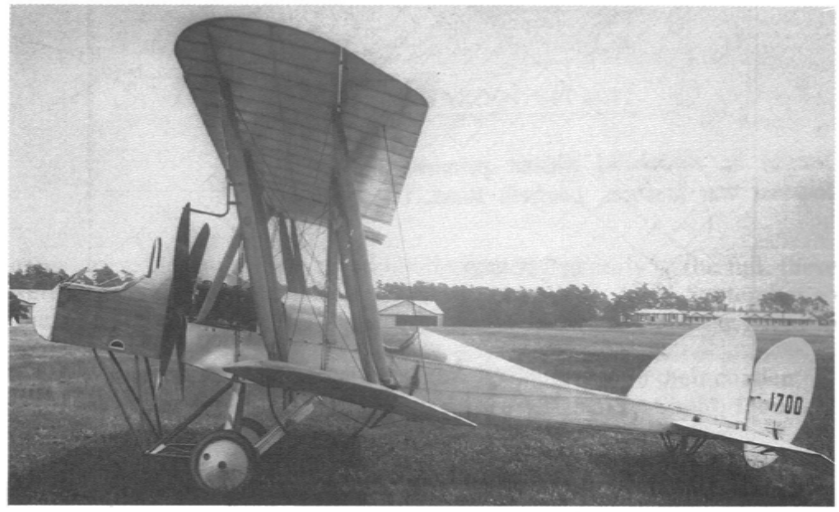
Powerplant:	80hp Gnome rotary 80hp Clerget 7Z
Dimensions:	
span	37ft 8½in;
chord	5ft 6in;
gap	6ft 3in;
wing area	368 sq ft;
length	27ft 4½in;
height	10ft 3½in.

Performance:
max speed 75mph at sea level;

B.E.9

As it became ever more apparent that the British flying services urgently needed an aeroplane suitably armed for an offensive rôle, and as no synchronisation mechanism was yet available to the Allies to enable a machine gun to be fired through the propeller disc, the most obvious solution appeared to be the pusher layout. However, although it offered an unrivalled forward field of fire, the pusher suffered from the additional drag of its tailbooms, and could never match the performance of a well-designed tractor of similar power. In a bold attempt to combine the pusher's field of fire and the tractor's performance in one aeroplane, the B.E.9 was conceived.

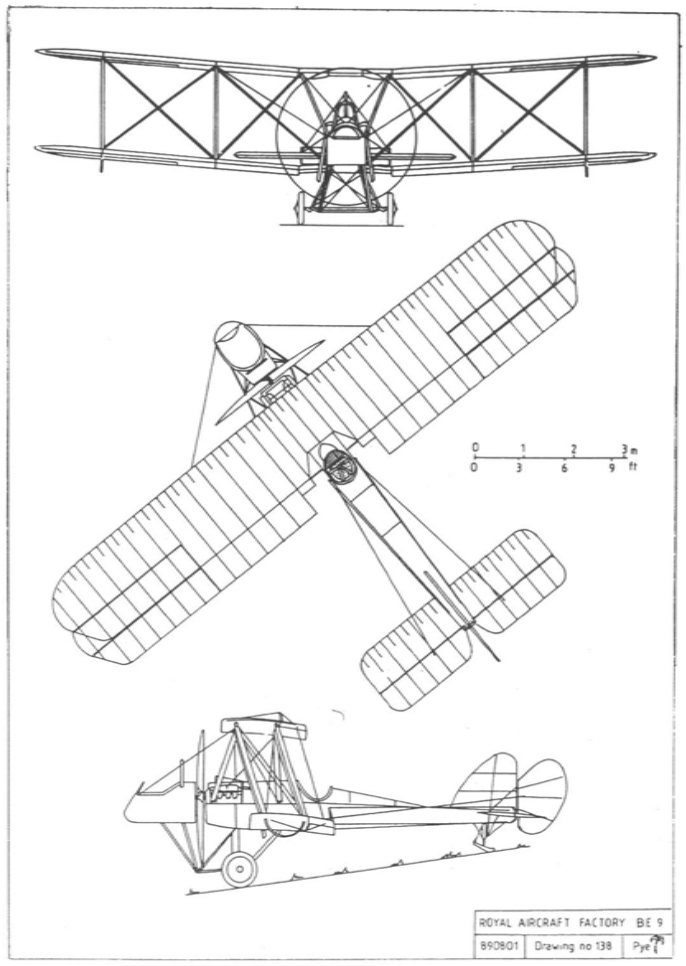
It was built, in mid-1915, by the conversion of the Bristol-built B.E.2c 1700, thereby continuing the tradition of 'reconstruction'. The observer's cockpit was eliminated, and the engine was moved back to occupy the space thus gained, the propeller being located about twelve inches in front of the leading edge of the upper wing. The wingspan was increased by the provision of a new, wider centre section, the cabane struts being raked outwards to clear the cylinders of the relocated engine. A gap was left at the root of the lower wing to improve the pilot's downward view. A plywood nacelle was mounted, via a ball-race, on the forward end of the propeller shaft, and braced to the undercarriage by a system of struts. Additional

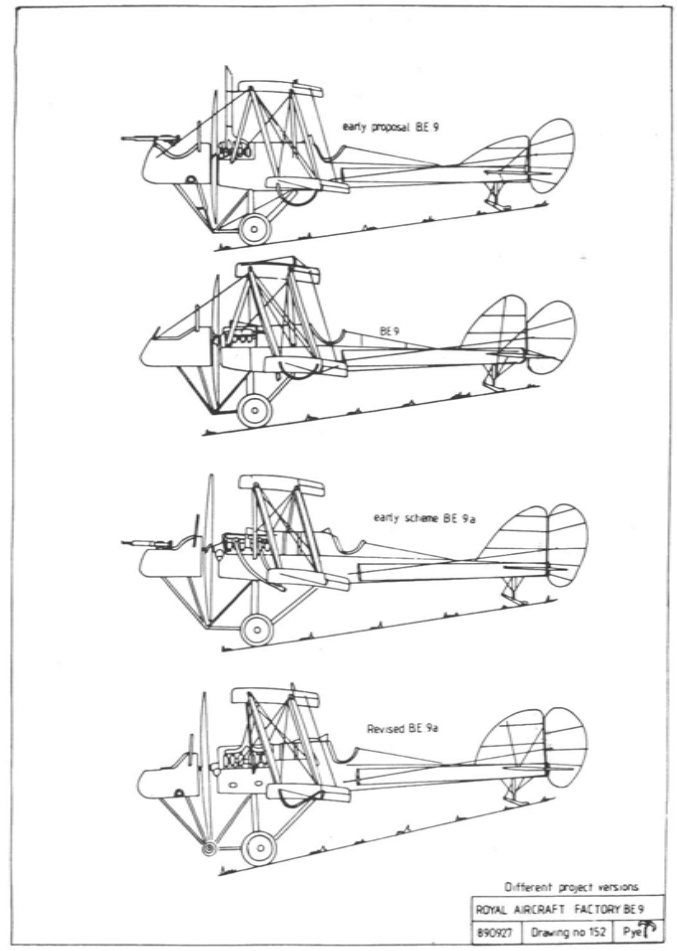


This view of the B.E.9 clearly illustrates the reason for the observer's sense of isolation.
(Imperial War Museum)

bracing was provided by wires running out to the wings. A greatly enlarged fin was fitted to offset the additional side area forward of the centre of gravity, but the standard rudder was retained.

The *Pulpit*, as it almost inevitably became known, was presented for final inspection on 14 August and taken up for a brief first flight later the same day, with Frank Goodden at the controls. It was passed to the Central Flying School for service trials, their official report finding the design 'excellent', the stability 'very good', and the speed only slightly reduced from that of the B.E.2c. Communication between the crew was regarded as 'difficult' (which was something of an understatement considering that they were separated by the engine and propeller), and the report recommended that dual controls should be provided. Although finding a route for the





necessary cables must have taxed the designers' ingenuity to the full, these were installed before the B.E.9 was flown to St Omer on 11 September so that it could be tested by crews from operational squadrons, Nos 6, 8 and 16 being among those selected.

Front-line pilots seem to have been almost unanimous in their condemnation of the machine. Lord Douglas of Kirtleside (then Lt Sholto Douglas) took it on a reconnaissance patrol over the lines on 26 October. He considered it 'ugly' and 'sluggish but very stable', and commented that his observer was, at best, 'lonely' in his little plywood box. Trenchard, then commanding the RFC in France, was equally unimpressed, and reported: 'this type of aeroplane cannot be recommended'.

The B.E.9 was therefore returned to the depot at St Omer and then, early

in the new year, flown quietly back to Farnborough, where it was never heard of again.

A French machine, the SPAD A-2, which was of similar design, was likewise not widely adopted and, although the concept was adjudged to have been a failure, it is perhaps unfair to condemn a brave, if misguided, solution to a pressing problem.

Powerplant:	90hp R.A.F.1a V-8
Dimensions:	
span	40ft 10½in;
chord	5ft 6in;
gap	6ft 3in;
stagger	2ft 0in;
length	29ft 0in;
height	11ft 5in.
Performance:	
max speed	82mph at sea level;
climb	4½min to 1,000ft.

B.E.9a

A plan to build a variant of the B.E. 9 powered by the 140hp R.A.F.4a was, considering the unsuitability of its forebear, not proceeded with.

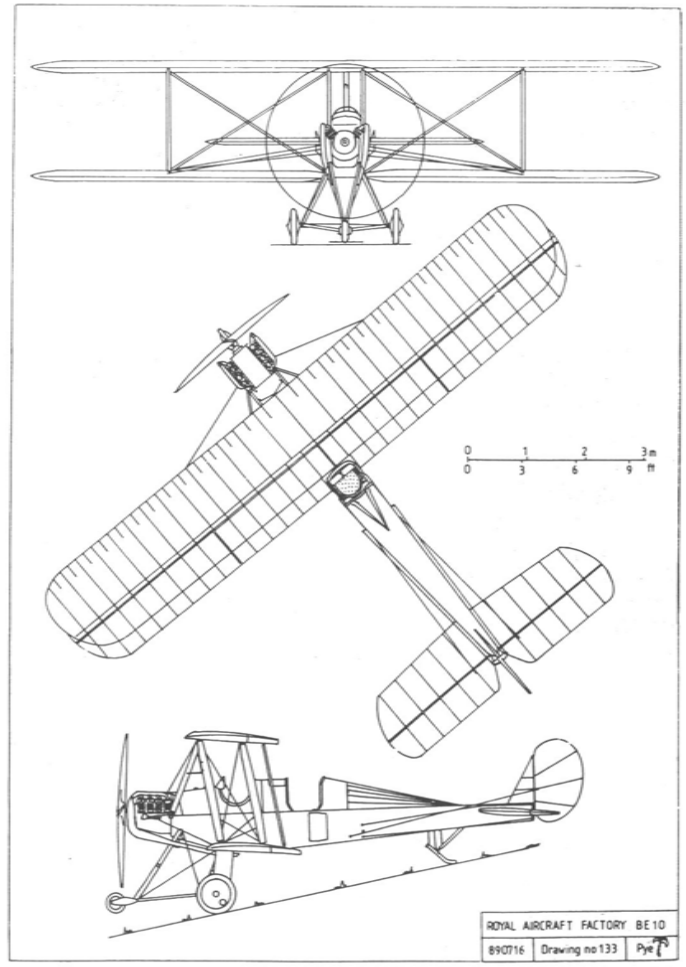
B.E.10

Designed in May 1914, the B.E.10 was developed from the B.E.2c but had a steel-tube fuselage frame, fabric covered and with a deeper coaming than on previous B.E. types, making it somewhat similar to that of the R.E.5. Its oleo undercarriage incorporated a small 'buffer' nosewheel. The wing span was slightly reduced from that of the B.E.2c, and the ribs were pressed from alloy sheet. The aerofoil section had a reflex trailing edge, and the full-span ailerons could be operated together as flaps. The rudder was of modified shape, and the small high-aspect-ratio triangular fin anticipated that later adopted for the R.E.8.

Surprisingly, power was to be provided by the rather outdated 70hp Renault, although it may well have been intended that the dimensionally similar 90hp R.A.F.1a would be substituted for full-scale production.

No prototype B.E.10 was built at Farnborough, but four examples were ordered from the British and Colonial Aeroplane Company. The order was cancelled soon after, when it was decided that the B.E.2c would remain the RFC's standard mount, and none were completed, although enough work was done for the Bristol employees to dub it the 'Gas Pipe Aeroplane'.

Powerplant:	70hp Renault V-8
Dimensions:	
span	35ft 8in;



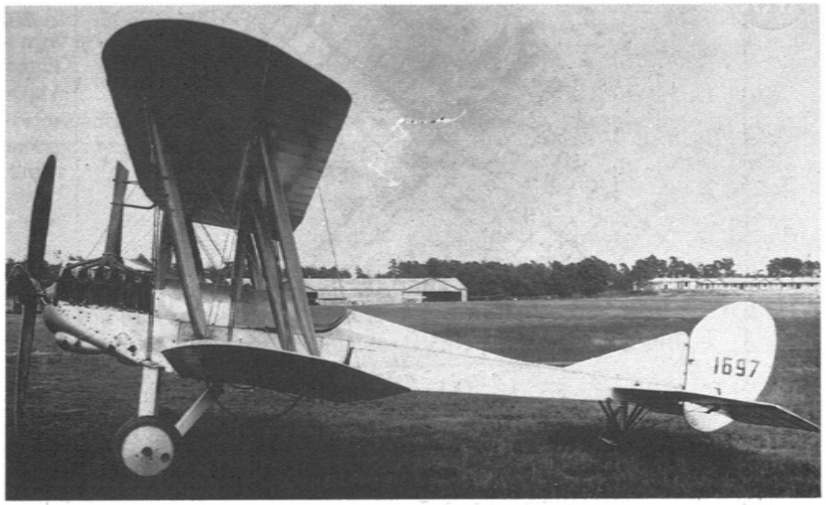
chord	5ft 4in;
wing area	355 sq ft;
length	27ft 1in;
height	10ft 9in.

B.E.11

No drawing or description of this project has survived, and it therefore seems unlikely that it ever progressed beyond the concept stage. It is almost certain that it was yet another variant upon the B.E.2 theme.

B.E.12

Conceived about May 1915, when the B.E.2c continued to be the most effective aeroplane operated by the RFC and serious aerial combat was still a thing of the future, the design which became known as the B.E.12 was intended to give improved performance for rôles such as bombing or photography, for which an observer was not usually carried. That it was not, initially, intended as a fighter is perhaps most clearly illustrated by the fact that the type had been in producton for several months before any attempt was made to fit a gun to it.



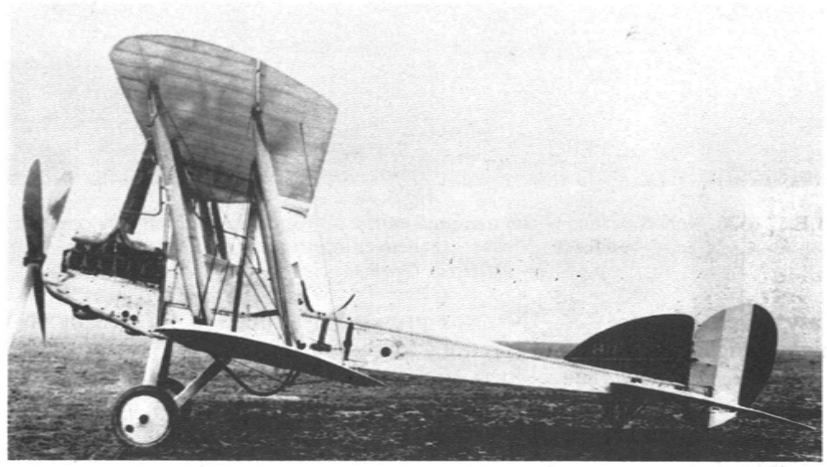
The prototype B.E.12. Note the tandem air scoops to cool its R.A.F.4a engine, and the complex exhaust system.

The prototype was created by the conversion of standard production Bristol-built B.E.2c 1697. The front cockpit was eliminated, and the engine bearers were modified to accept the 140hp R.A.F.4 V-12 engine. This had separate exhaust pipes from each cylinder, and they were led to a single vertical exhaust stack in the form of an inverted 'Y' on the aeroplane's centreline, where it can have done nothing to improve the pilot's forward view. Twin air scoops were mounted in tandem in the cylinder-head vee to assist engine cooling. A large pressurised fuel tank, shaped to follow the line of the fuselage top decking, was mounted between the centre-section struts. The skid-equipped undercarriage with which 1697 had originally been fitted was replaced by the more modern vee-strut type.

This work was completed by 28 July, when the machine was presented for its preflight inspection, and testing and development proceeded at a fairly unhurried pace thereafter. By the end of August a large, single air scoop had been fitted, necessitating the division of the exhaust into separate stacks for each cylinder bank.

The B.E.12 remained at Farnborough for most of the next month, supposedly for bomb-dropping experiments, although no evidence has been found of a bomb rack being fitted. On 22 September a larger, curved fin, as was to become standard for later B.E.2s, was fitted, and 1697 then went to France for service trials.

Production orders were placed with the Coventry Ordnance Works, the Standard Motor Company and Daimler, the last also undertaking production of the R.A.F.4a engine. Perhaps coincidentally, all three companies were based in Coventry.



Production B.E.12 6478. Its fin appears to be an in-service replacement, and has yet to have the machine's serial number painted on it.
(Military Aircraft Photographs)

Delays in engine manufacture held up completion of the first production B.E.12 until late March 1916, when Daimler-built 6478 arrived at Farnborough. Production aircraft differed from the prototype in having their upper fuselage longerons set down to a lower level forward of the cockpit, the engine mounting being similarly lowered. This improved the forward view over the engine air scoop, and allowed a larger petrol tank to be fitted. A streamlined gravity tank was also provided, under the port wing. Early examples had the original triangular fin, a larger fin of a type already fitted to 1697 being introduced later. All production machines were equipped with a camera mounting on the starboard side of the fuselage, outside the cockpit.

The prototype remained at the Factory and, from March 1916, was fitted with a number of experimental gun installations. Since there was still no British synchronisation gear, the initial installation, using a Lewis gun, featured blocks fitted to the propeller to deflect bullets. A later installation had the six-pounder Davis gun firing upwards at an angle of forty-five degrees, the muzzle being level with the top wing to place the breech within

B.E.12 6536. Note the Vickers gun mounted on the fuselage side, and the long operating rod for the Vickers-Challenger interrupter gear.
(PHT Green)

easy reach of the pilot. This was presumably intended for use against high-flying Zeppelins, but it was not adopted for service use.

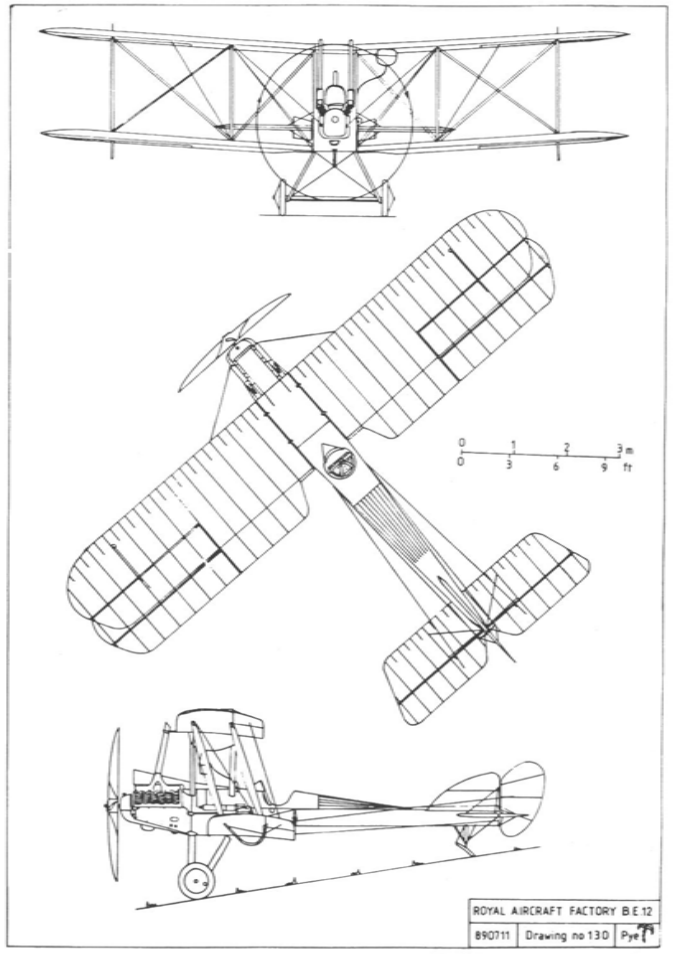
Finally, the newly developed Vickers-Challenger interrupter gear was adopted, operated a belt-fed Vickers machine gun mounted on the port side of the fuselage. The engine's air scoop prevented its installation in the favoured position on top of the decking, immediately in front of the cockpit. This fuselage-side mounting made jam clearing difficult, as the pilot had to reach far outside the cockpit. Unfortunately the sights also needed to be positioned on the aircraft's side for the same reason, forcing the pilot to lean out into the slipstream to take aim.

In mid-1916, in the wake of the 'Fokker scourge', the B.E.12 was pressed into service as a fighter, but its use in this rôle was soon curtailed following reports that it lacked even the limited manoeuvrability of the B.E.2c. In July the smaller tailplane designed for the B.E.2e was adopted for the B.E.12, and brought some improvement in handling, but the type quickly returned to the bomber rôle for which it had been designed, and in which it continued until February 1917.

Like the B.E.2c from which it was derived, its stability made it eminently suitable for use as a night fighter. It replaced the B.E.2c in this duty, and its greatest success occurred on 17 June 1917, when Lt L P Watkins of No 37 Squadron, flying 6610, brought down the Zeppelin L48.

Experiments in rendering aeroplanes less visible led, in February 1917, to the rear fuselage of 6148 being covered in transparent celluloid instead of fabric, but a lack of success is suggested by the early termination of the experiment.

Like many machines designed in the early part of the war, the B.E.12 continued in service for longer than its suitability dictated, new and less



demanding rôles being found as obsolescence approached. Thus the B.E.12 served almost to the end of the war as a trainer and on anti-submarine patrols, for which duty it was usually armed with two 112lb bombs.

The uprated R.A.F.4d, developing 200hp, was fitted to B.E.12 C3188 at the Orfordness experimental establishment, but no details of improvements in performance are available.

Powerplant:	140hp R.A.F.4a V-12
Dimensions:	
span	37ft 0in;
chord	5ft 6in;
gap	6ft 3¼in;
wing area	354 sq ft;

dihedral	3½°;
stagger	2ft 0in;
incidence:	4° 9″;
length	27ft 3in;
height	11ft 1½in.
Weights:	1,635lb (empty)
	2,353lb (loaded)
Performance:	
max speed	102mph at sea level;
	97mph at 6,000ft;
endurance	3hrs;
ceiling	12,500ft;
climb	6 min to 3,000ft;
	14 min to 6,000ft.

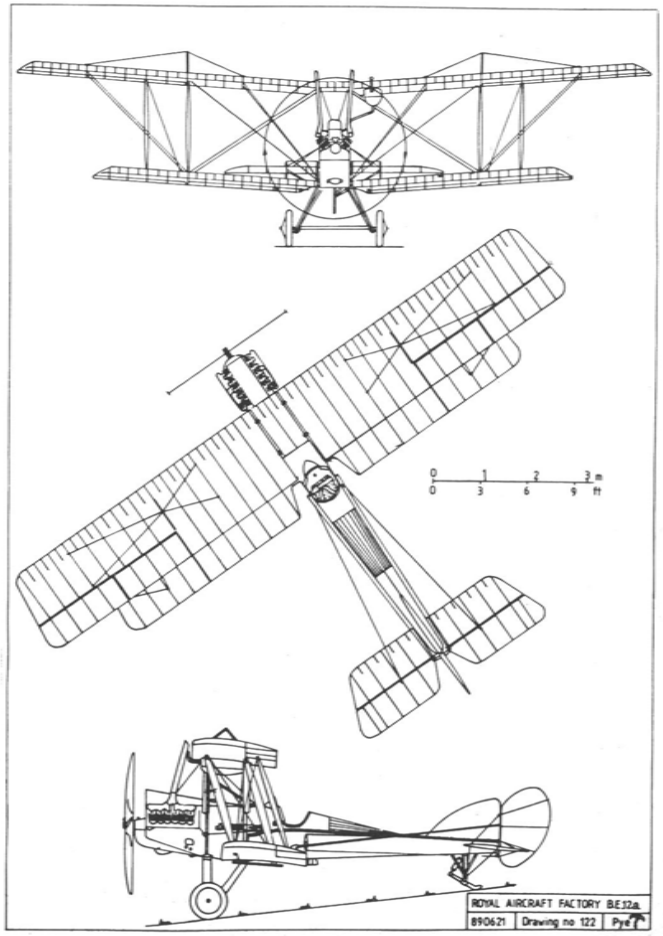
B.E.12a

Since the B.E.2e was viewed, at the time of its inception, as being almost infinitely superior to previous variants, it was inevitable that the B.E.12 should also be modified to have the new unequal-span wings. In this form the machine was initially designated the B.E.12Ae, but this was quickly simplified to the more conventional B.E.12a. Production orders, each for fifty aircraft, were placed with Daimler and the Coventry Ordnance Works.

The B.E.12a was initially judged to be easier to land and manoeuvre than its two-bay predecessor but, in reality, it showed little improvement over the earlier type and its use was largely confined to Home Defence units and the less-demanding theatre of operations in the Middle East. Some also served with the Royal Australian Air Force.

In November 1916 a new set of wings was constructed which had

Daimler-built B.E.12a A6303 before its armament was fitted.
(Capt DS Glover via PHT Green)



increased tip rake and included ailerons, incorporating large balance areas, on the top wing only. These wings were fitted to 6511, which had originally been built as a B.E.12, and on the 13th of that month Frank Goodden began flight tests. These showed no significant improvement in performance, and were reported to render the handling characteristics 'unpleasant', so the design was dropped, although a similar wingtip plan was reintroduced with the F.E.9.

Powerplant:	140hp R.A.F.4a V-12
Dimensions:	
span	40ft 6in (upper);
	30ft 6in (lower);
chord	5ft 6in;

stagger	2ft 0in;
gap	6ft 3in;
wing area	360 sq ft;
length	27ft 3in;
height	12ft 0in.
Weights:	1,610lb (empty)
	2,327lb (loaded)
Performance:	
max speed	105mph at sea level;
	93mph at 6,000 ft;
climb	5min to 3,000ft;
	11½min to 6,000ft.

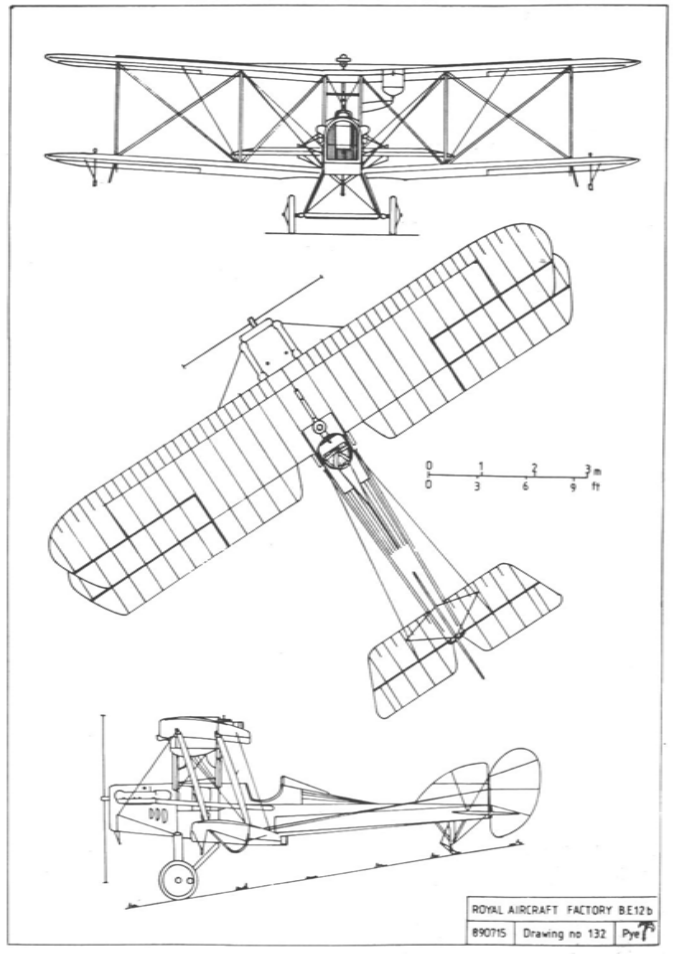
B.E.12b

Despite occasional successes by Home Defence squadrons, Zeppelin raids continued to cause widespread concern, and the raiders usually escaped simply because the defending aeroplanes lacked sufficient performance to reach the airships' normal operating altitudes in time to catch them.

A B.E.12b with its ground crew. Note the bomb racks under the wings and fuselage.

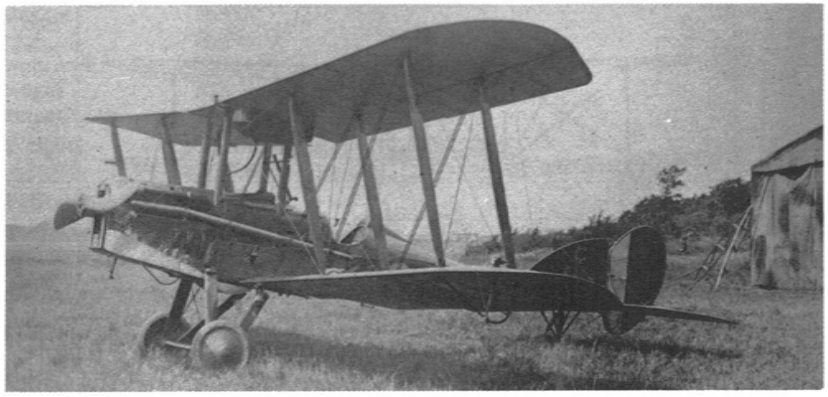
Therefore, in September 1917, a 200hp Hispano-Suiza engine was fitted to a B.E.12, this machine being preferred by service pilots to its single-bay successor. A car-type radiator gave the new machine a nose profile similar to that of the S.E.5, and long exhaust pipes, terminating aft of the cockpit, were fitted. It is possible that the installation was made by the Southern Aircraft Repair Depot, which shared the Farnborough site, but, whatever the case, the designers of the Royal Aircraft Factory were closely involved.

The new machine, designated B.E.12b, was found to possess a rate of climb so much improved that, despite the (ever-pressing) shortage of Hispano-Suiza engines or the licence-built variants, 100 examples were



ordered to be built by Daimler.

The B.E.12b was normally armed with a single Lewis gun on an overwing mounting, firing over the propeller disc, the wing shielding the pilot's eyes from the muzzle flash. Some examples sported twin guns, similarly positioned. A ring-and-bead sight was provided, fixed to the starboard centre-section struts. In view of their intended rôle as night fighters, B.E.12bs were provided with navigation lights and Holt flare brackets under their lower wingtips to facilitate landing. Some machines had exhaust pipes with their ends flared out to act as flame dampers. The normal B.E.12 fuel tank was retained but, as this was shaped to continue the slope of the air scoop needed with the R.A.F.4a engine, it was turned around so that it sloped upwards to the rear, thus reducing its resistance.



The reversed fuel tank of B.E.12b A3114 can be clearly seen between the centre-section struts.
(JM Bruce/GS Leslie)

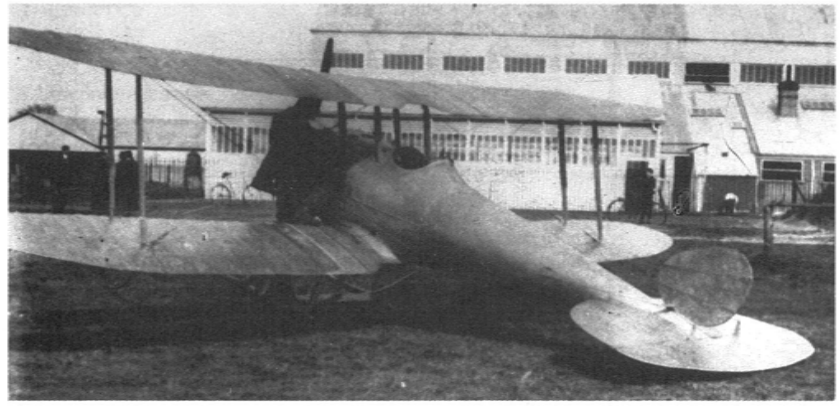
As the Zeppelin attacks had virtually stopped before many B.E.12bs could be built, few ever saw service. It is possible that many airframes never actually received Hispano-Suiza-type engines and may have been completed as standard B.E.12s powered by R.A.F.4as.

Powerplant: 200hp Hispano-Suiza V-8
Dimensions: As B.E.12a.

B.S.1

The design of this, the world's first single-seater scout, was undertaken by Geoffrey de Havilland, with assistance from Henry Folland and S J Waters. Its basic layout was scaled down from the B.E.3, though it had single-bay wings, an early use of such a bracing system. Lateral control was by warping. The streamlined fuselage was of circular cross-section, and the front section was built around four longerons which extended only from the engine mounting plate to a point some three feet aft of the cockpit. The rear fuselage was of true monocoque construction. Although the engine cowling allowed sufficient space for the 140hp two-row Gnome rotary which de Havilland considered might prove necessary to attain the desired speed, a smaller Gnome, rated at 100hp, was fitted initially.

Immediately behind the engine mounting plate was a divided tank holding twenty-two gallons of petrol and eleven gallons of oil, thus placing the disposable load on the centre of gravity. There was no instrument panel as such, the few instruments fitted—revolution counter, altimeter, airspeed indicator, watch and compass—being attached directly to the rear face of the fuel tank. The sturdy twin-skid undercarriage, which was typical of the period, was less aesthetically pleasing than the rest of the otherwise



The B.S.1 outside the Royal Aircraft Factory, showing the clean lines of its monocoque fuselage.
(Imperial War Museum)

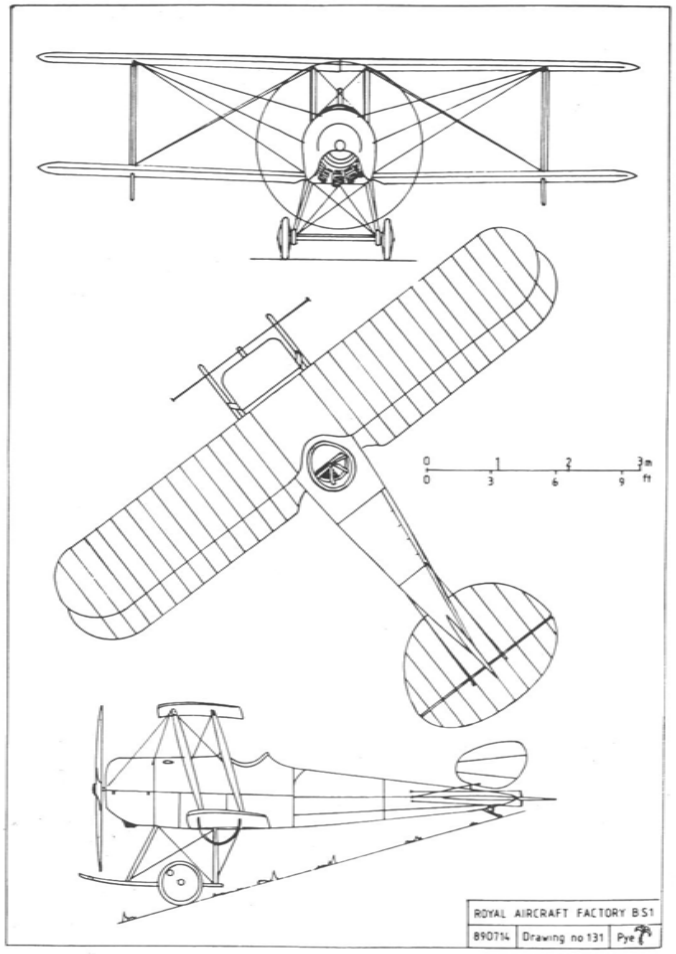
advanced design, although the wheel spokes were fabric covered to reduce drag.

The 'Blériot Scout' was completed early in 1913 and was test-flown by de Havilland on 13 March. Its maximum speed was in excess of 90mph, and its initial rate of climb was around 800ft/min. Control was light, but de Havilland thought that the rudder was too small, as a result of the scaling down from the B.E.3, especially as the covered wheels added keel area forward of the centre of gravity. By 25 March he had designed a larger rudder, but continued to fly the aeroplane with the original unit while waiting for the replacement.

Unfortunately, at about 5.00pm on 27 March, de Havilland went into a spin in the B.S.1 while turning at a height of about 100ft, proving his diagnosis regarding the rudder to have been correct, and crashed to the ground. His injuries, according to O'Gorman's report, were confined to 'two badly strained ankles and the loss of some teeth', but in fact he had also fractured his jaw. The report, which was intended for submission to the War Office, was probably composed to make as light as possible of the affair, and refers to the machine ' . . . smashing first the skids and then the bodywork', but as O'Gorman estimated the cost of repairs at £900 the damage was clearly much more serious than the description suggests.

Authority for the repair was eventually granted, and upon completion the aeroplane became known as the S.E.2 ('S' now standing for 'Scouting'). There is some evidence to suggest that it had already been thus redesignated at the time of its crash, and its continued career is described under that designation.

Powerplant: 100hp Gnome rotary
Dimensions:
span 27ft 6in



length	20ft 6in;
height	8ft 10in.
Weight:	1,232lb (loaded).
Performance:	
max speed	92mph at sea level;
min speed	51mph;
initial climb	800ft/min (approx).

B.S.2

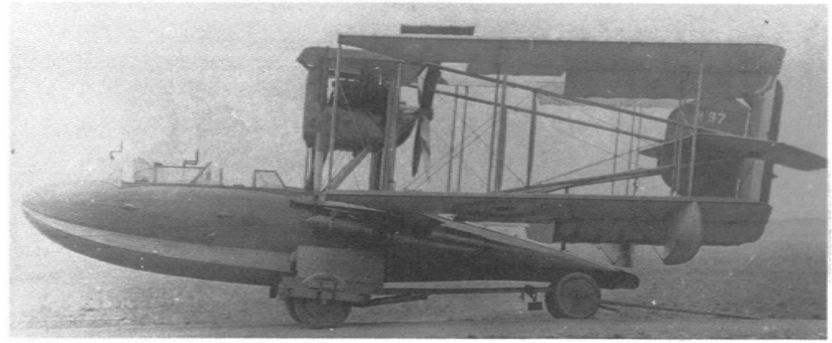
Few details are known of this machine, except that it was to have been rather larger than its predecessor, with a welded-steel-tube fuselage.

It has been suggested that it may have formed the basis for the design of the R.E.1.

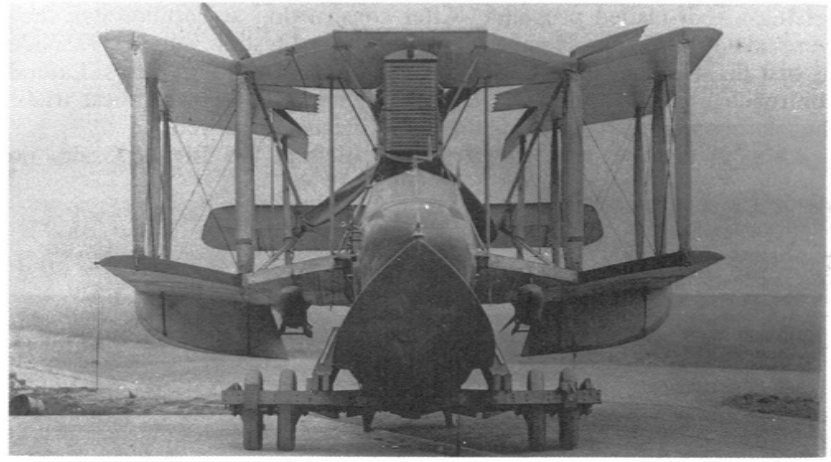
No dimensions known.

C.E.1

The Royal Aircraft Factory's only flying-boat design, the Coastal Experimental No 1 was first conceived in February 1917, to assist in combatting the growing threat to shipping posed by enemy submarines.



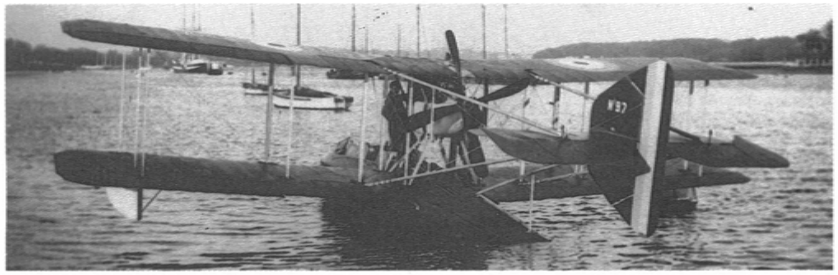
The C.E.1 N97 with its wings folded for storage.
(PHT Green)



A front view of C.E.1 N97, showing the bomb racks under its lower wings and the small sections of the upper wing trailing edge which hinged upwards to allow the wings to fold.
(PHT Green)

W S Farren had overall responsibility for the design.

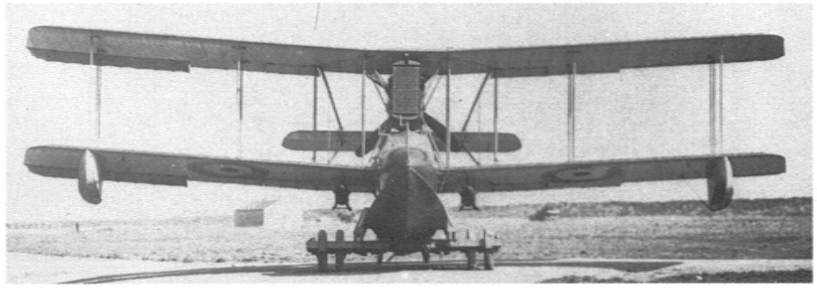
The C.E.1 was a two-seat pusher with a wooden hull which had a single step. The underside of the after portion was concave. Its empennage was carried on booms which met at the tailplane spar in a manner reminiscent of the F.E.8, and the fin and horn-balanced rudder were symmetrical above and below the tailplane. The wings were arranged to fold, the hinges being immediately outboard of the point at which the tailbooms joined the rear spar, a small section of the trailing edge having to be hinged upwards to make folding possible. Provision was made for up to three Lewis guns carried on pillar mountings, and for bombs carried beneath the lower wing.



The C.E.1 N97 afloat at Hamble.
(JM Bruce/GS Leslie)

Two prototypes were built, the first, N97, being powered by a 230hp R.A.F.3a and the second, N98, by a 260hp Sunbeam Maori, each engine driving a four-bladed propeller. After construction at Farnborough they were taken, in turn, to Hamble for assembly and testing, where N97 made its first flight on 17 January 1918, with its designer at the controls. Lateral control clearly gave some cause for concern because, following these trials, the ailerons were shortened and their horn balances removed.

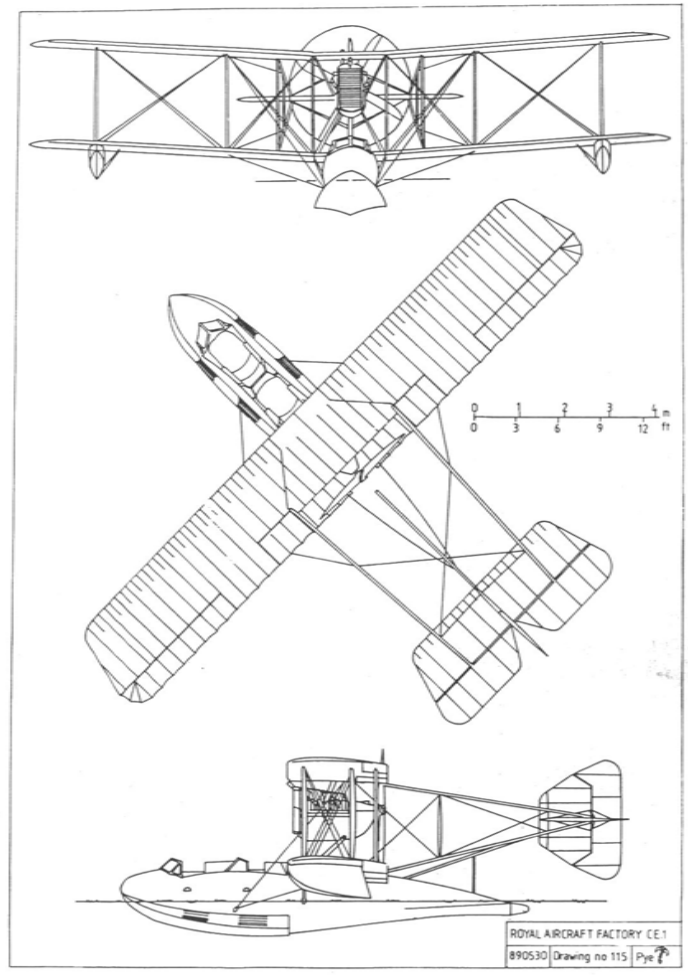
Although the type completed service trials at the Isle of Grain, no



The C.E.1 N97 on its beaching trolley at the Isle of Grain.
(PHT Green)

production orders were placed because the Felixstowe F.2 was considered superior. The two prototypes were then used extensively in experiments to verify data obtained from tests on model hulls conducted in the tank at the National Physical Laboratory, particularly with regard to 'porpoising' when in motion on the water. Their eventual fate is unknown.

Powerplant:	230hp R.A.F.3a (N97) 260hp Sunbeam Maori (N98)
Dimensions:	
span	46ft 0in
chord	7ft 0in;
gap	7ft 0in;



wing area	609 sq ft;
dihedral	3½°;
length	36ft 3in;
height	13ft 4in.
Weights:	
N97	3,241lb (empty)
	4,910lb (loaded)
N98	3,342lb (empty)
	5,000lb (loaded)
Performance:	
N97	
max speed	88mph at sea level;
ceiling	6,800ft
endurance	4½hrs.
N98	
max speed	92mph at sea level;
ceiling	7,500ft;
endurance	3¾hrs.

F.E.1

With £1,000 financial backing obtained from his grandfather in anticipation of a legacy, Geoffrey de Havilland gave up regular employment and built two successive aeroplanes of his own design. The first broke up on take-off, fortunately without injury to its creator, but the second was a success, and first flew on 10 September 1910, piloted by de Havilland. This was also his first flight.

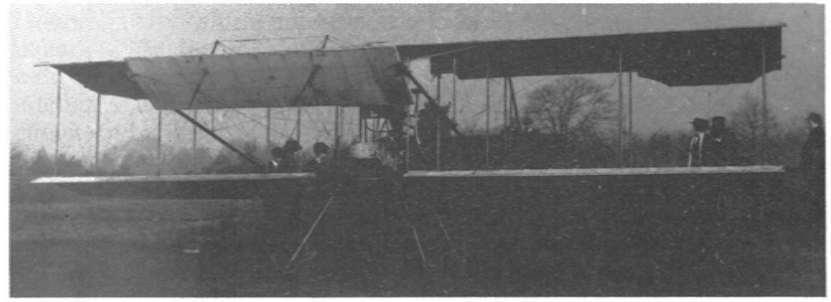
A conventional Farman-type pusher biplane with a forward elevator, it was powered by a 45hp horizontally-opposed four-cylinder engine which had also been designed by de Havilland and was built for him by the Iris Motor Company of Willesden, north-west London.

De Havilland used the machine to teach himself to fly and then, having

The de Havilland-built F.E.1.
(Military Aircraft Photographs)

almost exhausted the £1,000, he was appointed designer/test pilot at the Balloon Factory. At the same time he sold his aeroplane to the War Office for £400, subject to its passing acceptance trials which principally consisted of demonstrating its ability to fly for one hour without adjustment or repair. This de Havilland achieved on 14 January 1911, although, owing to the freezing weather, he was allowed to land twice during the test to thaw out.

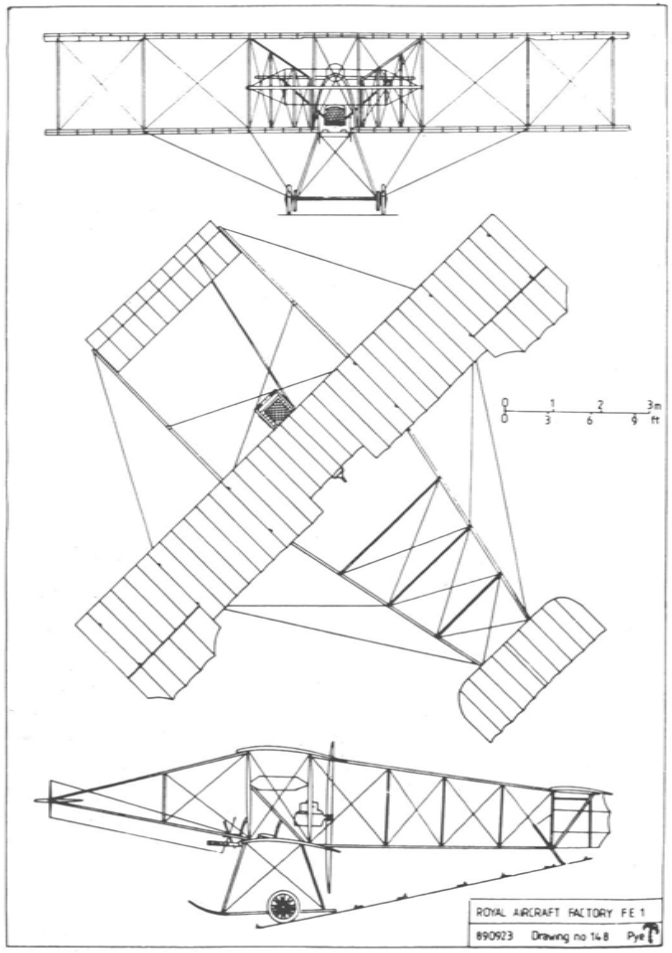
As Government property the aeroplane became known as the Farman Experimental or F.E.1. It was the first aeroplane to be classified in accordance with the Factory's system, and was the subject of continual development. First it was cleaned up aerodynamically, which included being fitted with new struts of improved streamline form. By the end of March its tailplane and rear elevator had been replaced by units of increased area, and by 11 April wing extensions had been fitted, enabling de Havilland to take up a number of passengers over the next few days. The extensions were removed early the following month because they were found to have an adverse effect on lateral control, but they were refitted by the end of the month, together with larger rudders, the Factory having realised that the existing rudders were not sufficiently powerful to overcome the drag of the ailerons when the extensions were fitted.



The de Havilland pusher biplane which became the F.E.1.

By June 12 the tailplane incidence had been increased so that it would produce additional lift, thereby taking all load off the forward elevator. The subsequent tests obviously proved satisfactory, as the F.E.1 was flown on 3 July with the front elevator removed. As usual the pilot was Geoffrey de Havilland, who reported that the fore-and-aft trim was not satisfactory. This problem was remedied overnight by re-rigging the wings to alter the position of the centre of pressure relative to the centre of gravity, and the machine was flown on numerous occasions throughout the month without further modifications. On 27 July de Havilland reached an altitude of 920ft, and the following day he gave short passenger flights to eighteen officers and men of the London Balloon Company Territorials, covering about eighty miles in the process.

Lt Theodore Ridge, the Factory's Assistant Superintendent, began to learn to fly on this machine in late July and early August, but on Tuesday 15



August he crashed while landing, damaging the engine, its mountings, the undercarriage and one lower wing.

There is no record of the aeroplane flying again, and officially it was 'reconstructed' as the F.E.2. However, as the latter was actually a totally new aeroplane and was already completed at the time of Ridge's crash, it is most probable that the F.E.1 was broken up for spares.

Powerplant:	45hp four-cylinder Iris-built de Havilland engine
Dimensions:	
span	33ft 0in
wing area	340 sq ft;
length	40ft 0in;
Weight:	1,100lb (loaded).

Performance:	
max speed	37mph at sea level;
endurance	1hr 20min.

F.E.2

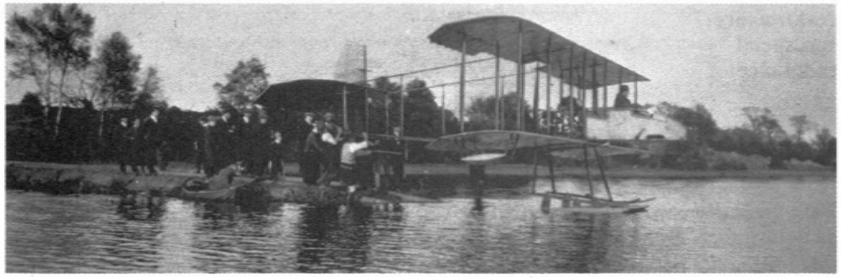
Two broadly similar but entirely separate aeroplanes each received the designation F.E.2 (without a suffix), although it is believed that the second machine was, officially at least, a rebuild of the first. In the same way it was, and occasionally still is, alleged that the first of the F.E.2s was a reconstruction of its predecessor, the de Havilland-built F.E.1. However, at the time of the F.E.1's last recorded flight, which was made on 15 August 1911 and ended in a crash, the F.E.2 was already complete and ready for flight, awaiting Geoffrey de Havilland's return from his holidays.

The wings, tail and undercarriage of the F.E.2 closely resembled those of the earlier machine, but there were numerous detail changes. These included a reduced cut-out in the upper wing centre-section, ailerons of increased span on upper and lower wings, and a simple nacelle to afford the crew some protection from the elements. Power was provided by a 50hp Gnome rotary which unfortunately proved to be a constant source of irritation. The first take-off, on 16 August, had to be aborted after a run of only fifty yards when a piston broke. This was replaced, and another attempt was made two days later when, despite constant misfiring, four circuits of Laffan's Plain were made. De Havilland, who was responsible for the machine's testing as well as for its design, reported that its lateral control was good but that it was tail heavy, and that, as a consequence, gliding was particularly difficult. Two further circuits were made on the evening of the same day with fifty pounds of lead in the nose, but the centre of gravity was still too far back. This problem was resolved by the end of the month, most probably by re-rigging, and de Havilland reported that the machine was 'flying well' and was very stable, although he felt that more rudder movement was required.

A test flight on 1 September, after the rudders had been modified, was cut short when an inlet valve broke, and the next flight, a few days later, was similarly abbreviated, the problem on this occasion being with the petrol feed. Engine troubles plagued almost every flight until 22 September, when de Havilland records that the engine was running better because the valves had been cleaned. On the same date the lower part of the machine's biplane tail was removed, and subsequently the wings were treated with the new dope Emaillite and a new propeller was fitted.

Finally the F.E.2 appears to have been satisfactory, and it made many flights, frequently carrying a passenger, throughout the remainder of 1911. In November it was fitted with dual controls, initially to the elevator and rudder only, but these were later provided for the ailerons as well.

On 6 December de Havilland flew the F.E.2 to Larkhill on Salisbury Plain, and then on to Shrewton, before returning to Farnborough, covering 100 miles in a flight time of 2¾hrs, this flight being one of the tests for his



The 1911 F.E.2 on floats. The age of the spectators suggests that they are not Factory employees.
(JM Bruce/GS Leslie)

Superior Aviator's Certificate. A climb to 1,900ft on 23 December appears to have been a further part of the qualifying tests.

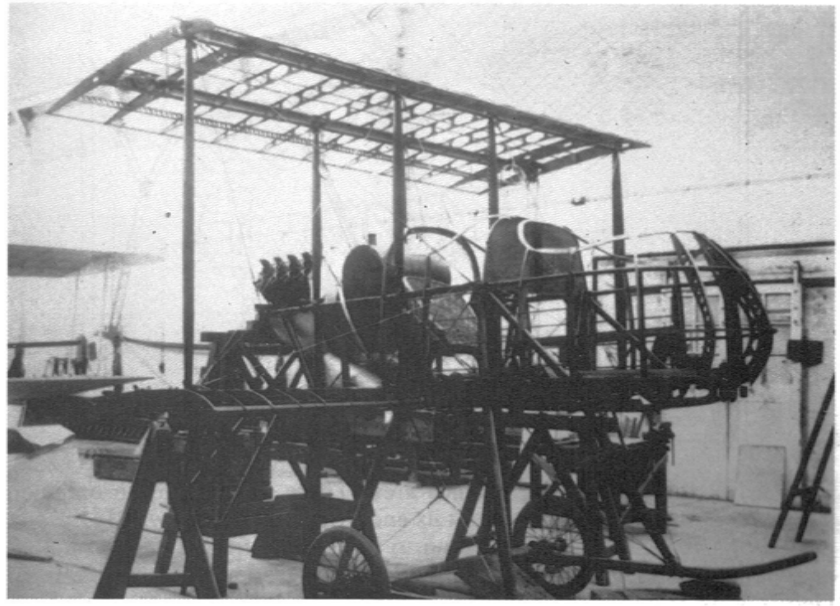
Some time in the new year (1912) a set of floats was designed to enable the F.E.2 to operate from water, and on 3 April the machine was flown to Fleet Pond, its wheels removed, and the floats fitted in their place. Problems were experienced in launching owing to the low level of the water, but once afloat the 'Hydro-Aeroplane' F.E.2 was found to ride well. The engine was started in the usual way, a mechanic wading into the shallow water to provide the necessary muscle power to swing the propeller. Steering was found to be as easy as on land, and then, after a run of about 100 yards, the machine took off, piloted by Mr Perry, and landed successfully after a short flight. Six flights were made in all, each of about a quarter of a mile and at a height of about twenty feet.

Later that month the troublesome engine was replaced by a new one, this time of 70hp, and on the 27th it was again flown to Fleet Pond, this time by de Havilland, for the floats to be fitted. Two days later it made a number of flights from the pond, again piloted by de Havilland, its increased power enabling a passenger to be carried. Curiously the experiment seems to have stopped at this point, and the results of the trials were reported to the War Office.* It is possible that the floats were transferred to the B.E.2 for similar trials.

Following its success as a seaplane, the F.E.2 was again modified, the intention on this occasion being to enable it to carry a machine gun. The undercarriage was strengthened and the tailplane re-set to balance the additional weight, and a belt-fed Maxim gun was fitted to the nose, where it could be aimed and operated by the passenger. Tests revealed that a gunner in such a machine was blessed with a wide arc of fire, but could only take advantage of much of the potential range of elevation by kneeling or standing up as appropriate. It was concluded that a special mounting giving a variable-height pivot point would be required to enable such a gun to be used effectively.

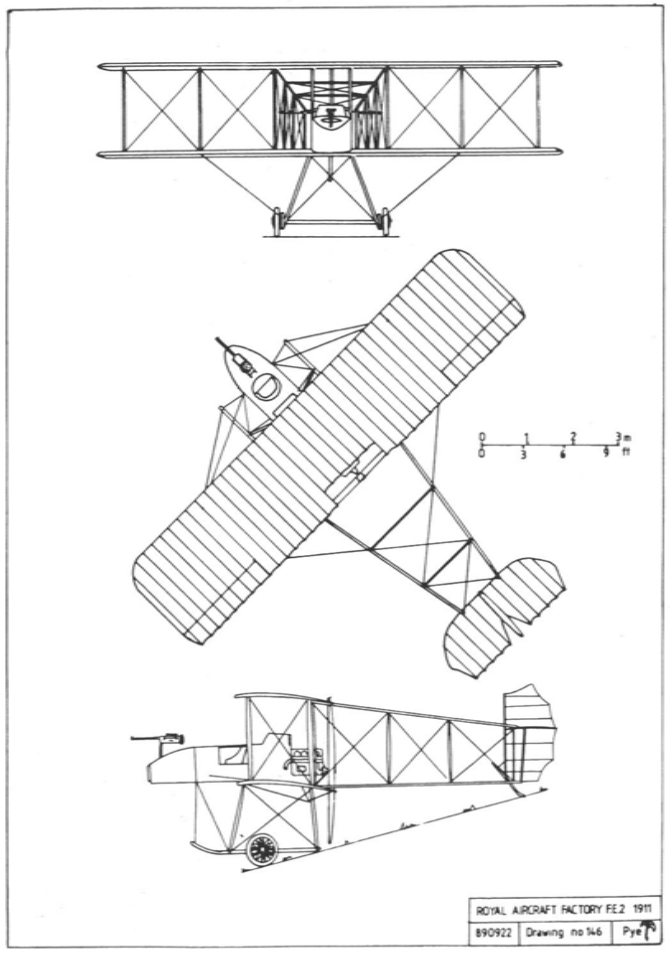
* 'Experiments with Hydro-Aeroplane'—PRO Air 1–2317/223/24/3.

The 1911 version of the F.E.2, fitted with a Maxim-type machine gun.
(Museum of Army Flying)



The nacelle of the 1913 F.E.2 under construction, with the 70hp Renault engine already installed.

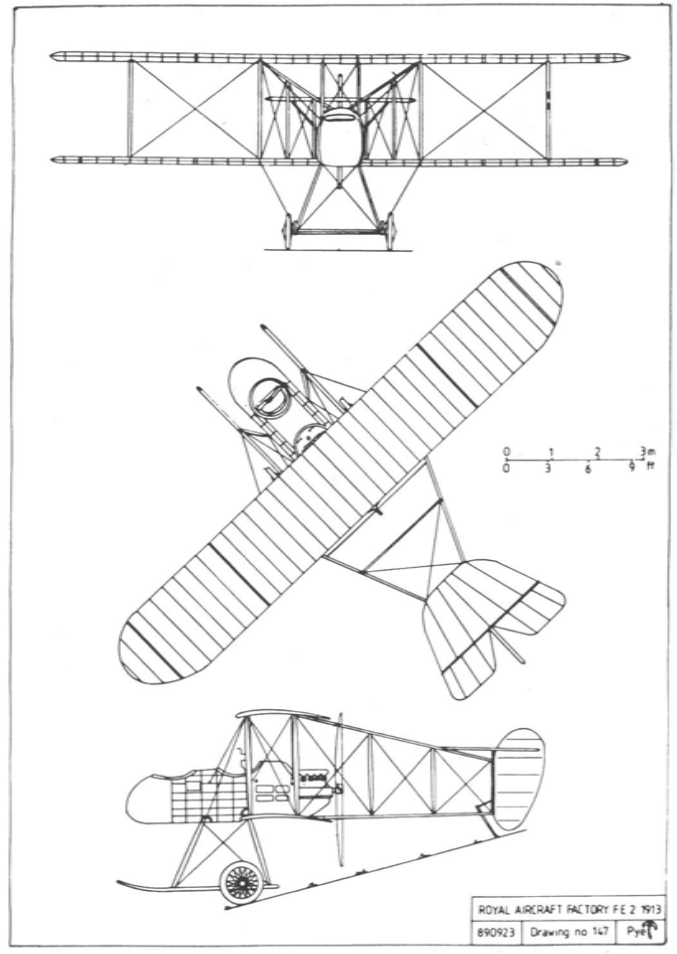
The second and separate F.E.2 was built during 1913, possibly using components from the earlier machine. It had a capacious but well streamlined nacelle, a 70hp Renault V-8 engine, and outer wing panels copied from those of the B.E.2. The monoplane tailplane was mounted on to the upper tailbooms and braced by struts to the lower booms. The rudder



was fairly large and had no balance area. There was no fin, an omission which very probably brought about its end, for on 23 February 1914, after a period of satisfactory testing, it spun to the ground from a height of 500ft and was wrecked. The pilot, Ronald Kemp, who had by that time replaced Geoffrey de Havilland as the Factory's chief test pilot, suffered a broken leg, and his passenger, Mr E T Haynes, was killed.

1911 version

Powerplant:	50hp Gnome rotary
Dimensions:	
span	33ft 0in
wing area	340 sq ft;
length	28ft 0in;



Weight:	1,200lb (loaded).
Performance:	
max speed	48mph at sea level;
initial climb	140ft/min (with passenger).

1913 version

Powerplant:	70hp Renault V-8
Dimensions:	
span	42ft 0in
wing area	425 sq ft;
length	30ft 0in;
Weight:	1,865lb (loaded).

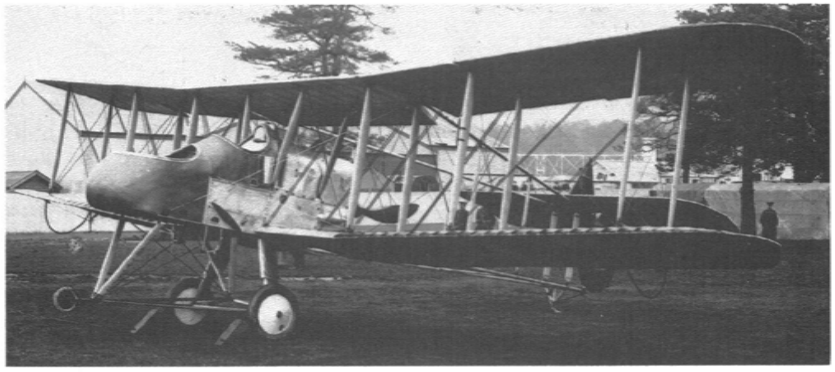
The 1913 version of the F.E.2, which had B.E.2a outer wings and a 70hp Renault engine.
(Military Aircraft Photographs)

Performance:

max speed	67mph at sea level;
initial climb	330ft/min;
ceiling	5,500ft.

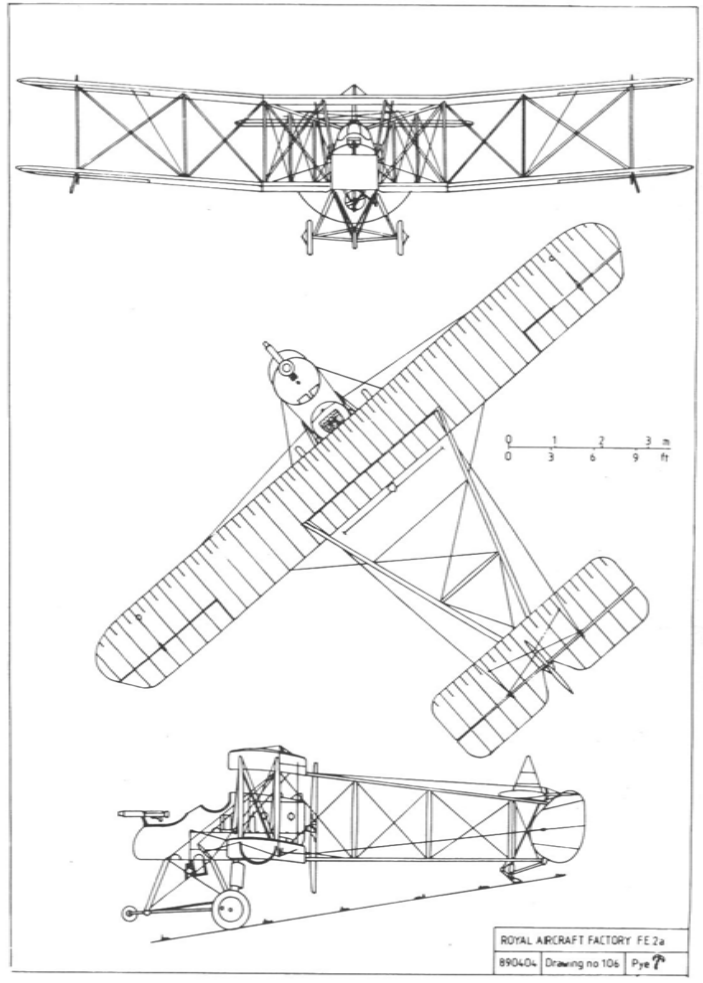
F.E.2a

In mid-1914 work was begun on a new version of the pusher format, incorporating lessons learned from the previous F.E. designs and intended, from the start, to carry a Lewis gun. Larger and heavier than the 1913 F.E.2 from which it was derived, the F.E.2a was designed to be powered by the



An F.E.2a. Date and location unknown.
(Military Aircraft Photographs)

six-cylinder, 100hp water-cooled Green engine which had won the Patrick Alexander Engine Competition, recently hosted by the Royal Aircraft Factory. The outer wing panels were again identical to those of the B.E.2, but this time were taken from the newest variant, the B.E.2c, and therefore incorporated ailerons. These wings were fixed to a centre-section which extended outboard to pairs of interplane struts at the tailboom attachment points, thus giving a three-bay wing structure. The tailplane was mounted on the upper tailbooms and wire-braced from a triangular kingpost which was fabric covered to provide fin area. Further fin area was provided by increasing the chord of the rearmost vertical struts between the tailbooms, and the rudder was aerodynamically balanced. The trailing edge of the wide



centre-section was hinged for use as an airbrake, and the undercarriage had oleo legs and a small buffer nosewheel.

In the atmosphere of urgency which followed the outbreak of war a batch of twelve F.E.2as was ordered off the drawing board. The first of these, 2864, made its first flight on 26 January 1915, piloted by Frank Goodden. Unfortunately the Green engine proved to be far too heavy for its power output, and it was therefore decided to substitute the 120hp Austro-Daimler which William Beardmore was by then building under licence in the company's own name. The first F.E.2a thus powered was flown, again by Goodden, on 16 March, and was found to be so much improved that the Beardmore engine was adopted for all the uncompleted F.E.2as. However, delays in engine production resulted in consequent delays in the completion of the aeroplanes, and deliveries dragged on all through the summer of 1915.

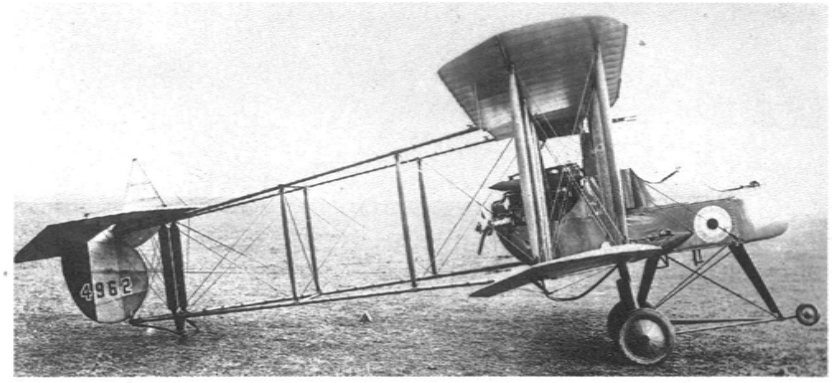
The last of the twelve, 5648, was delivered on 5 October. This machine differed from the rest in having a conventional vee-strut undercarriage and wings of R.A.F.14 aerofoil section instead of the R.A.F.6 of earlier machines, reflecting a similar change made to the B.E.2c. The flap-type airbrake was omitted from this machine as it was seldom, if ever, used by service pilots. An experimental braking parachute system which was tested during the spring of 1915 similarly found no favour, particularly as the landing run was not excessive anyway, and was not adopted for general use. This was, however, the first recorded use of such a device.

All twelve F.E.2as saw service with the RFC in France, and were among the few adequately armed aeroplanes that the force possessed. Had the type been available sooner and in greater numbers the struggle for command of the air might have been very different.

Powerplant:	100hp eight-cylinder Green 120hp six-cylinder Austro-Daimler (Beardmore)
Dimensions:	
span	47ft 9in
chord	5ft 6in;
gap	6ft 3½in;
wing area	494 sq ft;
incidence (R.A.F.6)	3½°;
length	32ft 3in;
height	12ft 7½in.
Weights:	1,993lb (empty); 2,680lb (loaded)
Performance:	
max speed	(100hp) 75mph at sea level; (120hp) 80mph at sea level;
ceiling	6,000ft;
climb:	8¼min to 3,000ft.

F.E.2b

Clearly impressed with the warlike potential of the first F.E.2a, the War Office ordered its mass production by a number of contractors. These mass-produced machines differed from the F.E.2a in a number of ways intended either to improve performance or to simplify production, and were therefore designated F.E.2b to distinguish them from the earlier model.



F.E.2b 4962 shows the complexity of the full oleo undercarriage.
(Military Aircraft Photographs)

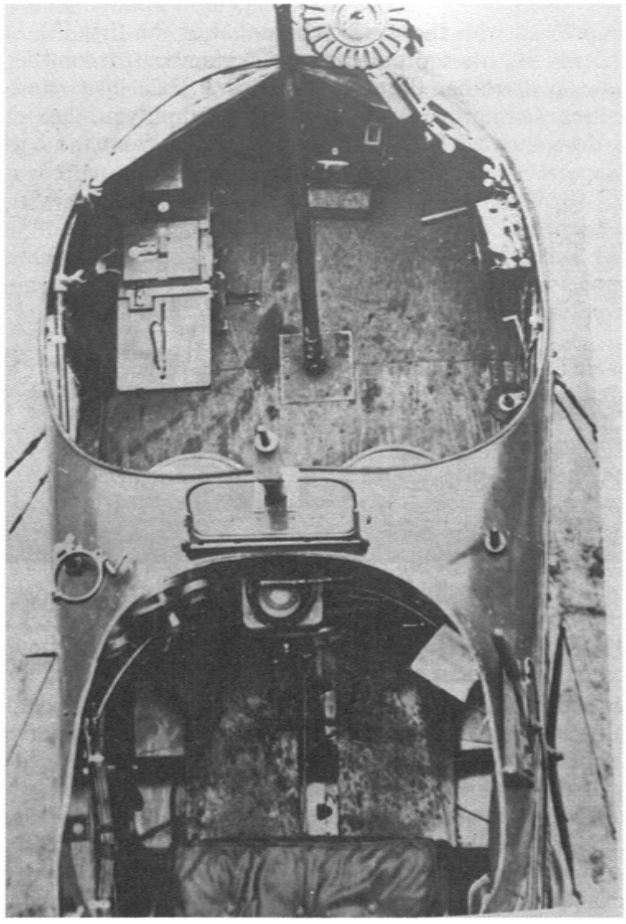
The upper centre-section was revised to eliminate the airbrake, which was not actually used in service, and the fully streamlined underwing gravity tank was replaced by a simpler unit which was easier to produce yet did not cause any significant loss of performance.

The drawings were quickly amended for issue to contractors, enabling the first F.E.2b, 5201 built by Boulton & Paul, to be delivered in October 1915, concurrently with the last of the F.E.2as.

Early examples were powered by the 120hp Beardmore engine and had wings of R.A.F.6 aerofoil section rigged at an incidence of 3½°. Wings of R.A.F.14 section were substituted early in 1916, following their introduction for the B.E.2c, and resulted in generally improved performance, although the rate of climb at altitudes above 5,000ft suffered slightly owing to the increased angle of incidence required by the new wings.

A need for increased endurance, combined with the adoption of the uprated and therefore thirstier Beardmore engine (which had an increased cylinder bore and gave 160hp), led, in March 1916, to the provision of an additional eighteen-gallon tank under the pilot's seat.

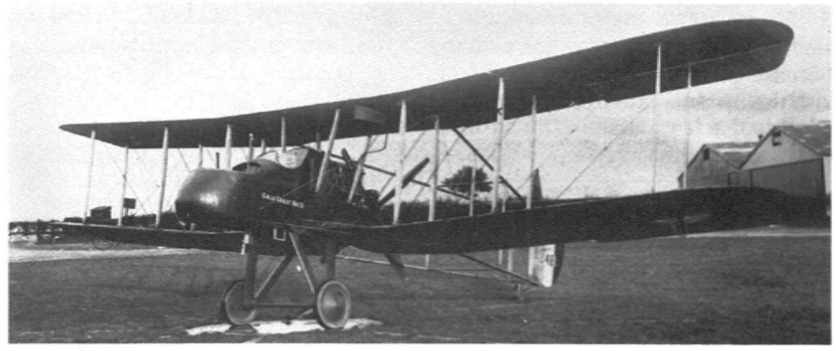
A variety of mountings were tried for the observer's Lewis gun, each giving an excellent field of fire forwards and to the sides, but defence against attack from behind depended upon the observer/gunner being sufficiently brave to stand up in the full force of the slipstream and fire backwards over the upper wing. Flights of the big pushers, known officially as 'Battleplanes'



The cockpits of an F.E.2b. The observer's Lewis gun is attached to the front pillar mounting, and alternative mountings are provided immediately in front of the pilot's windscreen and to each side of the nacelle, that on the port side having a fixing clamp already attached.

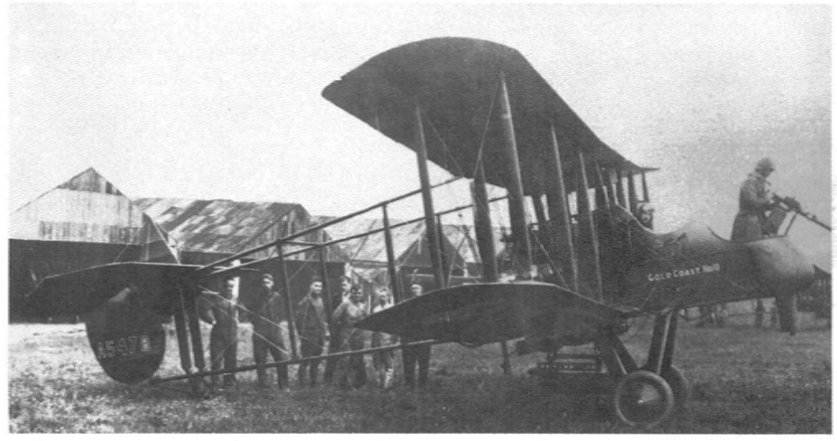
and affectionately as 'Fees', roamed the skies over the lines on 'offensive patrol', thus offering some protection to the unarmed reconnaissance machines and taking the war to the enemy in accordance with the beliefs of Brig-Gen Trenchard, Commander of the RFC in France. Their presence did much to combat the 'Fokker scourge' for, although they lacked sufficient speed to chase and catch the enemy fighters, they were formidable opponents once battle had been joined.

An effort was made to improve the F.E.2b's performance by replacing



Presentation F.E.2b A5481, *Gold Coast No 13*, fitted with a vee undercarriage. A pillar mounting for the Lewis gun can be seen to the rear of the observer's cockpit.
(via PW Pountney)

the efficient but fairly massive oleo undercarriage by a simple vee-strut structure similar to that common to other aeroplanes, such an installation having previously been made to the last of the F.E.2as. Although this modification obviously reduced drag and thereby effected a small but useful increase in speed and climb, the improvement was achieved at the expense of the machine's previous ease of landing, and the change was not universally popular within the RFC, being particularly unwelcome among the less experienced pilots. However, Lt Trafford Jones of 20 Squadron later devised a modification to the oleo undercarriage which greatly reduced its drag by eliminating the 'buffer' nosewheel, together with the struts needed to support it, while retaining its strength and efficiency. This simple



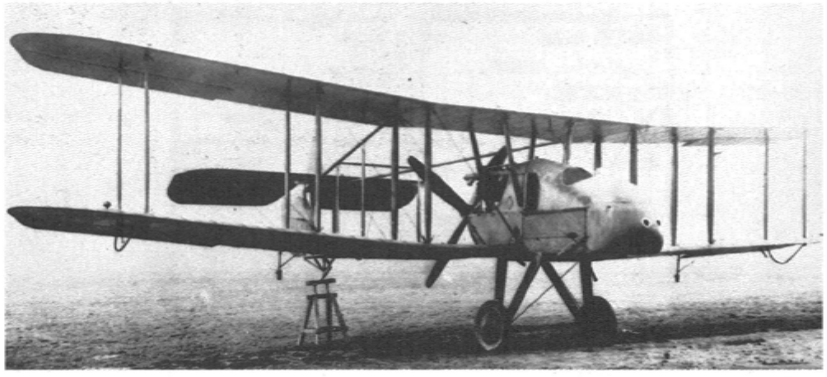
F.E.2b A5478 of 22 Squadron RFC with a full load of bombs. This picture shows the vulnerable position of the observer in combat.
(PHT Green)

modification was therefore adopted for all future F.E.2bs, and at the same time the lower longerons were changed from spruce to ash, presumably to increase their strength, because the landing shocks were less dispersed than with the original undercarriage.

Another view of A5478, showing the full extent of its bomb load. The projection beneath the nacelle is a flare chute.
(Museum of Army Flying)

By the middle of 1916 the rôle of the F.E.2b began to change as it became outdated as a fighter. The generous lift of its broad wings prompted its adoption as a bomber, a duty in which it continued throughout the war, switching to nocturnal operations as it became too far outclassed for daytime use. In this rôle its vee-strut undercarriage was found to be a definite advantage, as it allowed sufficient clearance for a 230lb bomb to be carried beneath the nacelle, which the oleo version did not.

Constant problems with the Beardmore engine, which often needed a complete overhaul after only a few hours' flying, led to the experimental installation of the only available alternative, the 150hp R.A.F.5, F.E.2b 6360 being so equipped in March 1916. However, the reduction in power



A single-seat F.E.2b, 9124, of 51 Squadron RFC, some time in 1918. The two small circular apertures in the nose are for the muzzles of its two Lewis guns.

cannot have enhanced the machine's already outdated performance, and no service machines were thus powered.

Experiments with the F.E.2b's armament continued throughout the war. A number had their nacelles modified to accommodate a quick-firing Vickers one-pounder together with a belt of forty shells, and a handful of such machines saw active service, being used in particular for attacks upon road and rail transport.

F.E.2b A781 fitted with a small searchlight coupled to two Lewis guns.
(Imperial War Museum)

F.E.2b B401 equipped for experiments in flying into balloon cables. Note the outriggers from the outermost interplane struts, carrying the fender wire to the bowsprit in the nose.
(via PW Pountney)

In October 1916 one example, 4928, was fitted with a small searchlight mounted on the undercarriage near to the nosewheel, the power being supplied by a propeller-driven generator mounted on the nose of the nacelle. An installation of a larger light was made on A781 in March 1917. This light had two Lewis guns attached to it, and was mounted on the

machine's nose, where it could be aimed by the observer. In this case the necessary generator was suspended below the front of the nacelle. Although they were designed with the intention of equipping the F.E.2b as a night fighter, these installations can only have been regarded as experimental, and neither was adopted for wider use.

Another experimental installation which was not adopted for service use was a device intended to deflect the cables of barrage balloons. This comprised a 'bowsprit' projecting from the nacelle, from which a stout cable extended to each wingtip. The aircraft thus equipped was deliberately flown into suspended wires by Roderic Hill, but a number of mishaps caused the tests to be discontinued before a fatality occurred.

A proposal, made in April 1918, that the F.E.2b should be used for anti-submarine patrols (the rôle for which the C.E.1 had previously been designed), led to the development of emergency flotation bags, fastened below the nacelle, for use if an engine failure forced such a machine to ditch into the sea. Trials, which included at least two ditchings, were successfully conducted at the Isle of Grain but, perhaps fortunately, there is no record of any pilot having to deploy the bags 'in anger'.

Use of the F.E.2b ceased almost immediately upon the signing of the Armistice, although one was retained at the RAE as a test vehicle until some time in 1924.

Only one example, D3822, found its way on to the civil register, spending a few years as G-EAHC with the Bournemouth Aviation Comany, giving joy rides.

Powerplant: 120hp six-cylinder (Beardmore) (later 160hp)

Dimensions:
As F.E.2a.

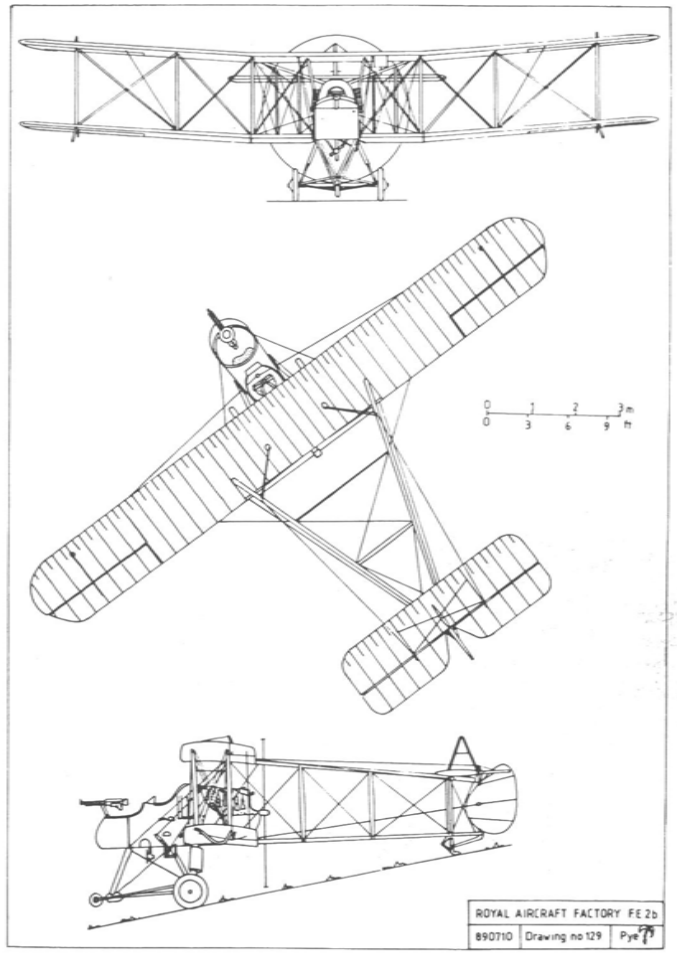
Flotation trials of F.E.2b 6536 at the Isle of Grain.
(Imperial War Museum)

Weights:

120hp	1,993lb (empty); 2,967lb (loaded).
160hp	2,061lb (empty); 3,037lb (loaded).

Performance:

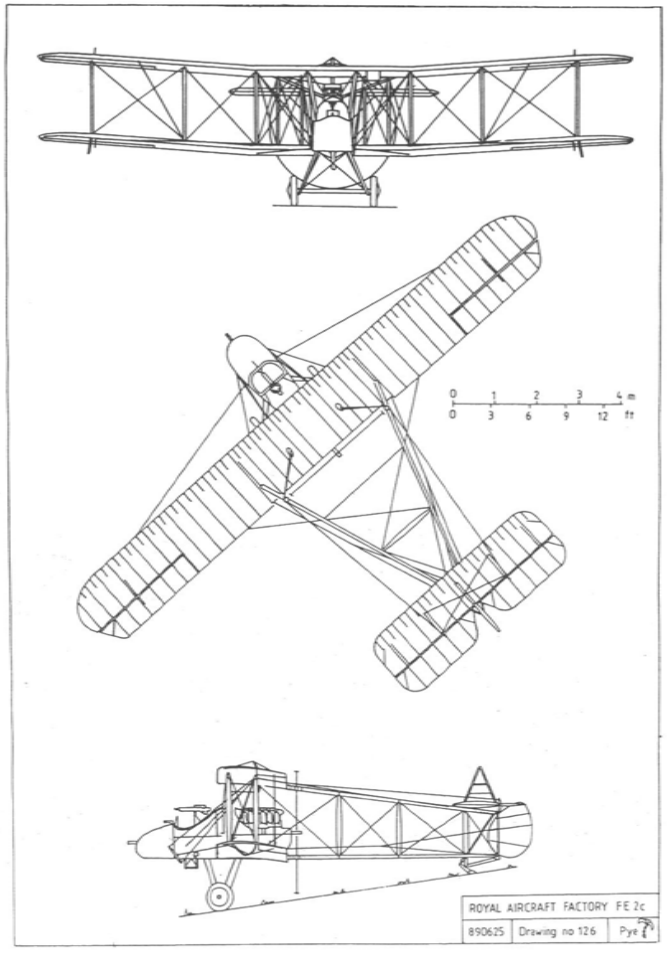
120 hp	
max speed	80mph at sea level;
ceiling	9,000ft;
climb:	9min 50sec to 3,000ft.
160hp	
max speed	88mph at sea level; 92mph with vee undercarriage;
ceiling:	11,000ft;
climb	7min 24sec to 3,000ft;
endurance	3hrs.



F.E.2c

The first machine to bear the designation F.E.2c was built as an F.E.2a (possibly either 5644 or 5646), and had the crew positions reversed to place the pilot in front but was otherwise of normal configuration. This modification was apparently made to improve the pilot's view, particularly for night landings, but the change so restricted the observer's field of fire that the idea met with little favour from its intended users, a situation which the provision of a forward-firing Lewis gun for the pilot did little to improve.

At the same time, October 1915, the Factory was adapting a number of production F.E.2bs to the new configuration and, in view of the pilot's disapproval, work was stopped when only two, 6370 and 6371, had been converted. The former machine was retained at Farnborough for continued trials, but 6371 was sent to France in April 1917, possibly in the erroneous belief that it was a standard F.E.2b, and served briefly with 22 Squadron before being written off in a crash in July.



The final appearance of the type was made late in 1917, when six F.E.2bs were converted to the 'c' configuration, with the pilot's cockpits in front, and served with 100 Squadron. They were probably equipped with Vickers quick-firing guns.

Dimensions: As F.E.2b.

F.E.2d

In what now seems to have been an almost desperate attempt to improve the performance of the sturdy but somewhat sluggish F.E.2b, a new variant, designated F.E.2d, was designed early in 1916, powered by the 250hp Rolls-Royce Eagle V-12 engine. The airframe remained unaltered except for those detail changes necessary to accommodate the new engine, but the fuel system was modified to allow the storage of an additional twelve gallons of petrol.

The prototype, 7995, was completed, ready for inspection, by 4 April 1916, and flew for the first time three days later with Frank Goodden at the controls. Although the massive increase in power brought about only a small increase in top speed, and manoeuvrability and landing speed were adversely affected, the rate of climb and service ceiling were sufficiently improved to justify its adoption, especially as the Beardmore engine normally used in the F.E.2b was far from reliable. Production was therefore undertaken at the Royal Aircraft Factory and by Boulton & Paul of Norwich.

The Factory seems to have worked with commendable dispatch, and A1, the first of a batch of forty machines, was completed by the end of May. The

An F.E.2d, showing the unshuttered radiator. The airship sheds in the background were, at that time, the home of the Southern Aeroplane Repair Depot.

last machine was delivered by the end of August.

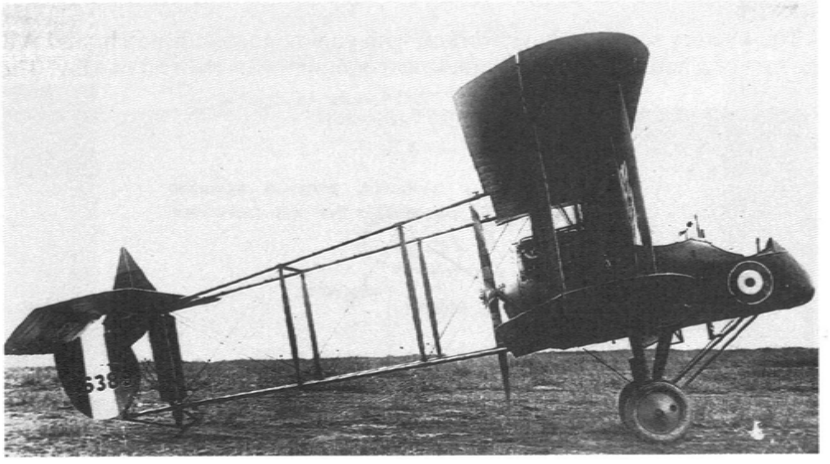
To facilitate the removal of the massive engine from its mounting, surrounded by tailbooms and bracing wires, the Factory designed a portable hoist with which the engine could be lifted clear and lowered to the ground or on to a bench.

The radiator designed for use with the Rolls-Royce engine was found, in practice, to be too large, resulting in excessive cooling. Although shutters, operated by the pilot, went some way towards alleviating the problem, they relied principally on his intuition for correct operation, and provided a distraction which was wholly unwelcome in a combat aircraft. The final solution turned out to be remarkably simple; the radiator previously used for the Beardmore engine was substituted, but installed without the cowlings fitted to the earlier variants so that it received the full effect of the airflow. Shutters were still fitted to allow a faster warm-up, especially during colder weather.

The modification to the oleo undercarriage which eliminated the nosewheel, and which was already in use on the lower-powered F.E.2b, was tested on the '2d' towards the end of August 1916, and was adopted for all new machines with effect from 15 October.

Unfortunately the German air force became familiar with the new machine almost as quickly as did the RFC, for A5, one of the first F.E.2ds to go to France, was ferried across the Channel by an inexperienced crew and inadvertently landed, without serious damage, on the wrong side of the lines, near Lille, effectively making a present of it to the enemy.

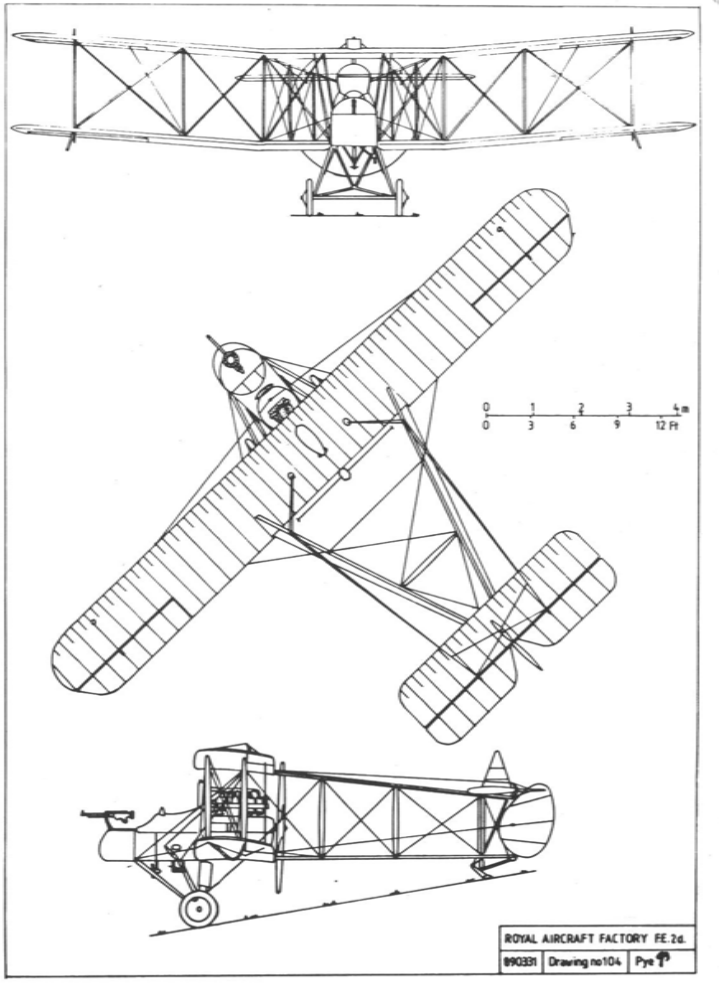
The F.E.2d had originally been conceived as a stopgap until the problems with the 160hp Beardmore engine could be resolved, and some machines, ordered as Rolls-Royce-powered '2ds' were actually completed with the smaller engine. The type continued in service, alongside its forebear, the far



An F.E.2d with the Trafford Jones modification to its oleo undercarriage.
(Military Aircraft Photographs)

more numerous F.E.2b, and many other, newer designs until the end of the war.

In April 1917 work was started on the design of a seaplane version of the F.E.2d, but before much work had been done the scheme was dropped in favour of the C.E.1 project.



Powerplant:	250hp Rolls-Royce Eagle V-12
Dimensions:	
span	47ft 9in;
chord	5ft 6in;
gap	6ft 3½in;

wing area	494 sq ft;
length	32ft 3in;
height	12ft 7½in.
Weights:	2,509lb (empty); 3,469lb (loaded).
Performance:	
max speed	97mph at sea level;
ceiling	17,000ft;
climb	6min to 3,000ft;
	14½min to 6,000ft;
endurance	3½hrs.

F.E.2e, f, g & h

Although relatively few details survive of the variants to which these designations were applied, it is recorded that the F.E.2h was a standard F.E.2b or d modified to accept the 230hp Siddley Puma in an effort to conserve stocks of the Rolls-Royce Eagle, which was in great demand for other designs, while producing an aeroplane of equivalent performance.

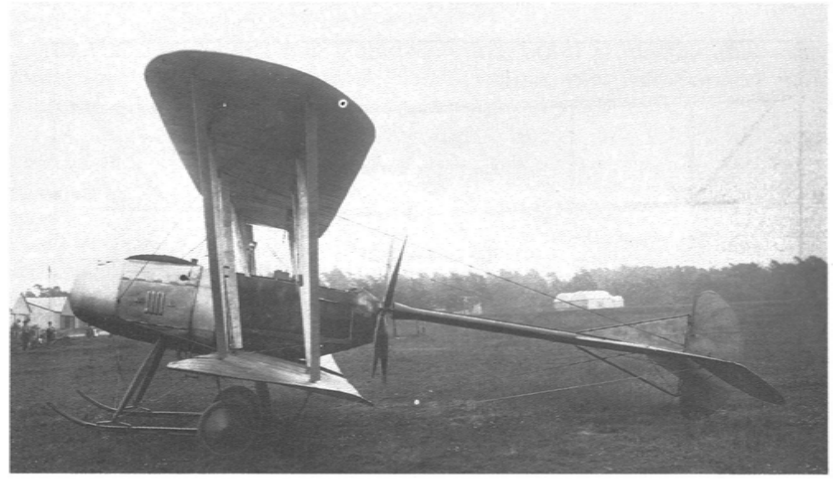
The prototype was produced late in 1917 by the conversion of an existing F.E.2d, A6545, the actual work being undertaken by Ransomes, Sims & Jefferies. Testing at Martlesham Heath, with both vee and oleo undercarriages, was undertaken early in 1918, and proved that the new variant's performance was little better than that of the F.E.2b and much lower than that of the Eagle powered F.E.2d. Nevertheless, three more Boulton & Paul-built machines, A6501–6503, were converted to the Puma engine, the work again being undertaken by Ransomes, Sims & Jefferies. These were renumbered E3151–3153, and were tested at the Isle of Grain armed with the recoilless six-pounder Davis gun.

Various other engine installations were tested, including the R.A.F.5, and all failed to find approval. It is believed that the remaining designations were to have been applied to these machines if they were placed into production, thereby forestalling the confusion which had arisen with the early B.E.2es.

Powerplant:	230hp six-cylinder Siddeley Puma
Dimensions:	
As F.E.2d.	
Weights:	2,280lb (empty); 3,355lb (loaded).
Performance:	
max speed	93mph at sea level;
ceiling	14,000ft;
climb	11½min to 6,000ft;

F.E.3 (A.E.1)

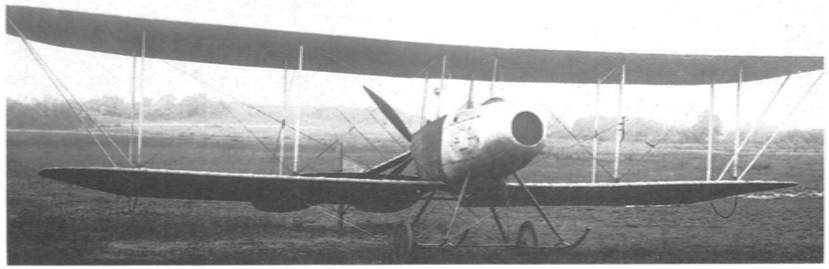
This quite remarkable two-seater, which included several novel and ingenious design features, was built in 1913 and was also known as the A.E.1, or Armed Experimental. It was conceived expressly to carry a Coventry Ordnance Works (COW) gun, which fired a one-pound shell, in an effort to provide the flying services with a weapon for which it was confidently expected there would be an eventual demand, although there was no immediate need. S J Waters appears to have had overall responsibility for the design, assisted by messrs Beadle, Folland, Reynolds and Swan.



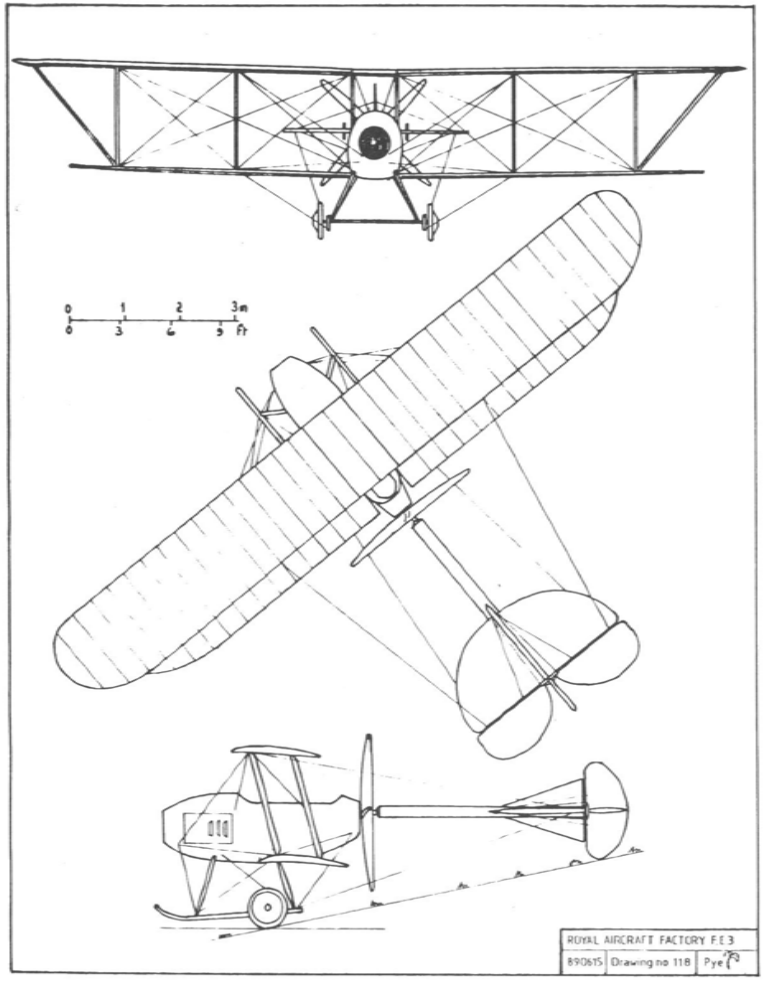
As with many aeroplanes of its time, the F.E.3's streamlined appearance was rather marred by the heavy undercarriage considered necessary to cope with unprepared aerodromes.
(Royal Aerospace Establishment)

As was almost inevitable for a gun-carrier, the machine was a pusher, power being provided by a water-cooled, six-cylinder in-line Chenu engine of 100hp. This was mounted well forward in the nacelle so that, in the event of a crash, there was no risk of it breaking free and crushing the pilot, a common failing of most pushers. A shaft extended rearwards from the engine along the bottom of the nacelle, driving the propeller via a chain running in an oil-tight case behind the pilot's seat. In an attempt to eliminate the drag of the braced tailbooms normally associated with pusher designs, the tailplane was carried on the end of a single tailboom which was supported on bearings at the end of the propeller shaft and by bracing wires running to the upper wing and to the undercarriage.

Surviving drawings suggests that there was some indecision as to how the fully enclosed engine was to be cooled. At least one drawing shows extensive surface radiators along the top of the nacelle, following its contour



The F.E.3. The opening in the nose admitted cooling air to its internally mounted radiators.



from nose to cockpit rim. However, as finally built, the forward portion of the nacelle was clad in aluminium sheet, over a framework of steel tube, and the remainder was clad in plywood. The radiators were mounted inside the nacelle, cooling air being admitted through a circular hole in the nose. The wing and tail surfaces were of entirely conventional construction, being of fabric covered spruce, and their design clearly owed a great deal to the contemporary F.E.2, as did the undercarriage.

Test flying, undertaken by Geoffrey de Havilland, assisted by Ronald Kemp, revealed that the tail was not sufficiently rigid for satisfactory service, and the tests were discontinued without the gun being fired in flight. It was, however, tested with the machine suspended from the roof of one of the Farnborough airship sheds to establish that the gun's recoil would not pose a problem in flight.

The F.E.3's eventual fate is not recorded, but it is possible that rather more than the lessons learned from its trials was incorporated in its successor, the F.E.6.

Powerplant:	100hp eight-cylinder Chenu
Dimensions:	
span	40ft 0in;
chord	5ft 9in;
gap	6ft 4in;
wing area	436½ sq ft;
incidence	3°
dihedral	1½°;
length	29ft 3in;
height	11ft 3in.
Weights:	1,400lb (empty); 2,080lb (loaded).
Performance:	
max speed	75mph at sea level;
ceiling	5,000ft;
climb	350ft/min to 1,000ft.

F.E.4

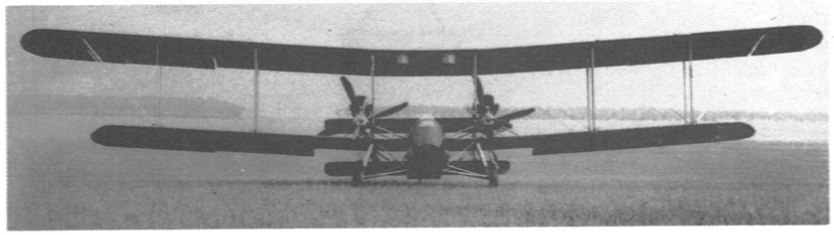
In mid-1915 a team led by S J Waters and Henry Folland undertook the design of a twin-engined pusher biplane designated F.E.4, the basic layout of which was based upon the results of windtunnel tests intended to establish the most effective configuration. The machine was somehow intended to meet three rather diverse requirements:

a Ground-attack fighter, armed with a one-pounder Coventry Ordnance Works gun and with an endurance of four hours.
b Short-range bomber, with a 1,200lb bomb load and a three-hour endurance.
c Long-range bomber with eight hours endurance, albeit with an appropriately reduced bomb load.

The last specification was the specific request of Brig-Gen Trenchard, Commander of the RFC in France and thus the aeroplane's ultimate 'end-user'.

The F.E.4 was a big aeroplane, particularly by the standards of 1915, with a wing span greater than 75ft. The overhanging extensions to the upper wing were arranged to fold downwards, a feature which was intended to facilitate storage but which, in reality, merely added unnecessary complexity to the machine's structure.

The pilot was placed in the extreme nose, with an observer/gunner immediately behind him. Dual controls were provided, a facility which most crews would consider obligatory in a machine for which an endurance of up to eight hours was planned. Since the observer would clearly be unable to defend the machine's tail against attack, a third crew position was provided behind the wings to house a rear gunner. A revised drawing was later prepared in which this gunner is repositioned in a streamlined nacelle above the top wing centre-section, giving him an enormous field of fire, but this modification does not appear to have been incorporated in an actual aeroplane. In the same drawing the auxiliary nosewheels are replaced by small semi-circular skids.



The first F.E.4, with R.A.F.5 engines. Note the small tractor propellers and huge air scoops essential to assist engine cooling.
(JM Bruce/GS Leslie)

Although it was originally intended that the F.E.4 should be powered by two R.A.F.3a engines, none was available for installation in the prototype and two lower-powered R.A.F.5s were substituted. These, the pusher version of the air-cooled R.A.F.4, had small tractor propellers to ensure that there was an adequate movement of cooling air over the engines at all times.

The prototype, which was given the serial 7993, was completed ready for AID inspection on 8 March 1916, and made its first flight a few days later, with Frank Goodden at the controls. It proved to be woefully sluggish, as might have been expected with engines developing only three-quarters of the power for which it had been designed, and could barely exceed 80mph, compared with the 100mph anticipated by its designers.

Despite its shortcomings, which were not apparent to a casual observer, it was demonstrated to King George V during his visit to Farnborough on 26 April. On 11 May it went to the Central Flying School for evaluation, and

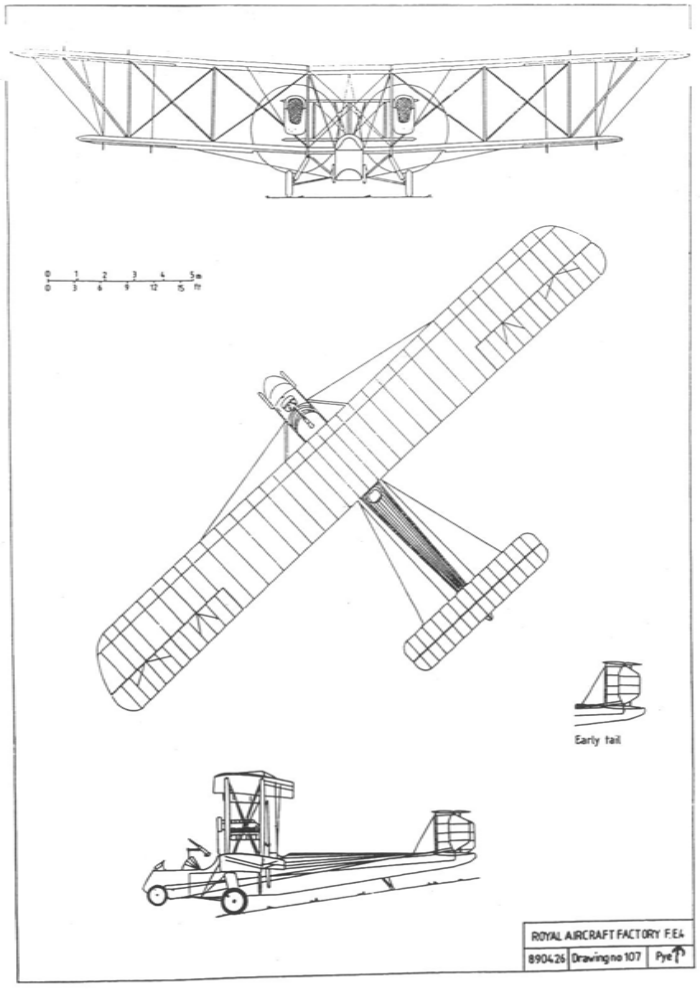
The first prototype F.E.4, 7993, in P.C.10 finish at the Central Flying School for service trials.
(JM Bruce/GS Leslie)

was found to be stable but pitifully underpowered.

As there were still no R.A.F.3as available, a second prototype, 7994, was converted to accept 250hp Rolls-Royce Eagle engines, complete with radiators similar to those used on the F.E.2d. At the same time the total fuel capacity was increased from 193 gallons to 250. There was no rear gunner's cockpit. This machine, to which the designation F.E.4a has often, but erroneously, been applied, did not fly until 5 June 1916, again with Goodden in the pilot's seat. Despite the increased power the performance was still wholly unremarkable and, since there were many obviously superior designs available, the trials were discontinued and the Rolls-Royce engines, for which there was an insatiable demand, were removed for use in other aircraft. A production order for 100 machines, which had been placed with Daimler, was cancelled before any could be completed.

Both prototypes were still extant in July 1917, but a suggestion that they should be pressed into service as night bombers, a duty for which their lack of speed was no real handicap, was not taken up owing to a continued shortage of suitable engines. They were eventually broken up.

Powerplant:	2 × 140hp R.A.F.5a 2 × 250hp Rolls-Royce Eagle
Dimensions:	
span	75ft 2in (upper); 62ft 6in (lower);
chord	9ft 0in (upper); 7ft 6in (lower);
wing area	1,032 sq ft;
length	38ft 8½in;
height	16ft 9in
Weights	
(R.A.F.5a):	3,754lb (empty); 5,988lb (loaded).
(Eagle):	7,825lb (loaded).
Performance:	
(R.A.F.5a)	
max speed	84mph at sea level;



ceiling	6,000ft
(Eagle)	
max speed	92mph at sea level;
ceiling	12,000ft.

F.E.5

Although it was never completed, this ambitious project showed great potential. It was to have been a twin-fuselage, three-engined development of the F.E.4, powered by two tractor 140hp R.A.F.4as mounted in the nose of each fuselage, and a pusher R.A.F.5 mounted centrally on the lower

wing. Intended as a heavy bomber, and designed with a wing span in excess of 100ft, the F.E.5 would almost certainly have been as painfully underpowered as the original F.E.4, and may well have been abandoned for that reason.

In common with many other Royal Aircraft Factory projects, the F.E.5 was the subject of windtunnel testing during its design, the tests being described at length in the Advisory Committee's report for 1916–17.

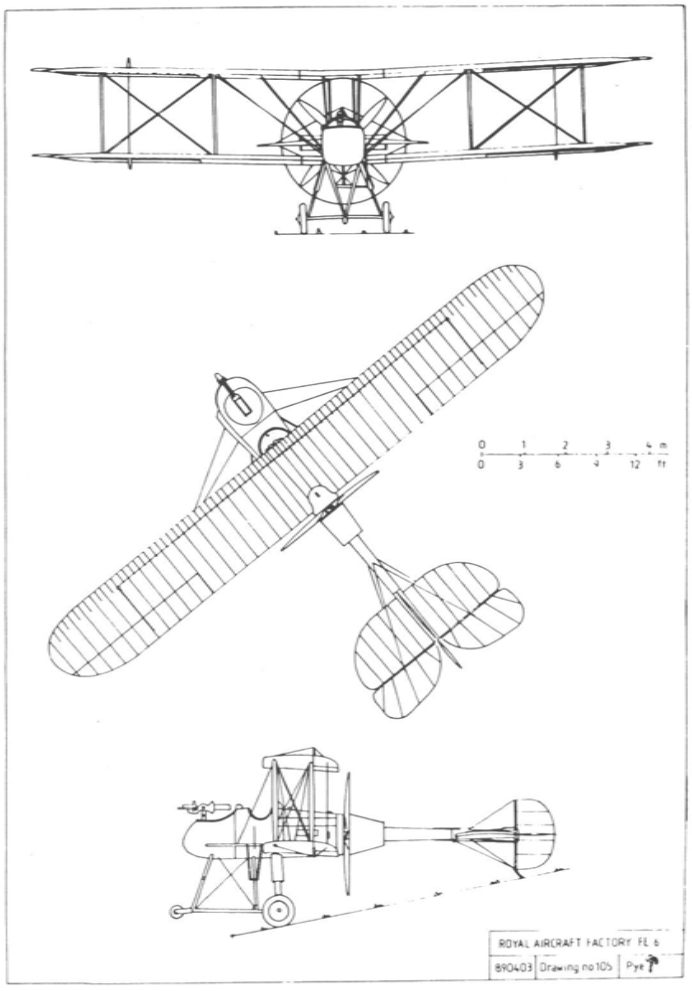
Dimensions Span 103ft 0in.

F.E.6

Designed early in 1914, the F.E.6 continued to explore the ideas previously incorporated in the F.E.3 and, like its predecessor, carried a one-pounder quick-firing Coventry Ordnance Works gun. It closely followed the layout of the earlier machine and was again a pusher, but, being a slightly heavier design, it was powered by the more powerful 120hp six-cylinder Austro-Daimler. The wings were standard R.E.5 components, and the tall oleo undercarriage incorporated a small nosewheel, making it very similar in appearance to that of the F.E.2b. The tail surfaces, like those of the F.E.3, were carried at the end of a single tubular tailboom attached to a bearing on the end of the propeller shaft. Unlike the boom of the earlier machine, this one was a cantilever structure, with no bracing wires to support it. The control wires operating the rudder and elevators were run inside the tailboom tube, thus eliminating another potential source of drag.

The F.E.6's fin and rudder, in common with those of many of its contemporaries, appear to have been of insufficient area to balance the keel area forward of the centre of gravity. This may have been one of the reasons why its flying career, at the hands of Frank Goodden, was very brief. Following a test flight on 14 November 1914, a heavy landing resulted in some damage to the undercarriage, but the aircraft was not repaired. Instead the machine was broken up, the wings being returned to store as R.E.5 spares. As with the F.E.3, it is extremely doubtful if the gun was ever fired, at least not while the machine was in flight.

Powerplant:	120hp eight-cylinder Austro-Daimler
Dimensions:	
span	49ft 4in;
chord	6ft 0in;
wing area	542 sq ft;
length	29ft 6in;
height	15ft 0in.
Weights:	2,000lb (empty);
	2,630lb (loaded).



F.E.7

Another uncompleted design project developed from the F.E.4 concept, this big biplane was to have been powered by two 250hp Rolls-Royce engines mounted within the fuselage, driving twin pusher propellers via gears and shafts.

It was clearly intended for an offensive rôle, as proposals for its armament appear to have included the one-pounder COW gun, with which its designers seemed to be obsessed, as its main weapon. Several Lewis guns were provided for defence. It was also planned for use as a long-range or

heavy bomber, but the design was not completed and no machines were built.

Dimensions
Span 67ft 9in

F.E.8

By mid-1915 it had become evident that the Royal Flying Corps was in fairly urgent need of a single-seater fighter (or 'Scout', in contemporary parlance), both to afford some protection to its vulnerable two-seaters and to take the war to the enemy by attacking German aircraft.

Such a machine obviously needed to be equipped with a forward-firing gun, placed within easy reach of the pilot so that it could be loaded and any jams could be cleared. As the Allies still lacked a workable gun synchronisation system, the only practicable solution was to make the new machine a pusher, despite the drag penalty and consequent reduction in performance.

The aeroplane which the Farnborough team, headed by John Kenworthy, designed to fill this rôle was broadly similar in concept to its closest 'rival', the D.H.2, produced contemporaneously by the Aircraft Manufacturing Company, where Geoffrey de Havilland was then chief designer, but it differed almost totally in detail.

The single tubular tailboom previously employed in the F.E.3 and F.E.6 was abandoned, despite its reduced drag, because its structural integrity was still far from proven. Instead, conventional steel-tube tailbooms were employed, but these were arranged to meet, unconventionally, at the tailplane spar, rather than at the sternpost. They thus formed a vee in elevation and not, as was common, in plan. The tailplane incidence was adjustable, although only on the ground and, to reduce overall weight and control forces, the rudder and elevator ribs were of duralumin. The nacelle, which was of conventional appearance, was built upon a triangulated framework of welded steel tubing which eliminated any need for internal bracing wires, the shape of its duralumin covering being maintained by wooden formers. The high-aspect-ratio, two-bay wings were rigged with five degrees of dihedral outboard of the wide centre section. Ailerons spanned all four outer wing panels, and on the early F.E.8s no spanwise balance cables were fitted, the ailerons being returned to their normal position by rubber bungees.

Power was provided by a 100hp Gnome monosoupape rotary driving a four-blade propeller which, for some inexplicable reason, was fitted with a conical spinner.

Instrumentation was typically spartan, comprising only a tachometer, altimeter, airspeed indicator, transverse clinometer, watch holder, compass, and fuel pressure gauge (this being vital as no gravity tank was fitted, and the engine would cut out if the pressure within the tank fell too low. A hand pump was provided for emergency use).

The first prototype F.E.8, showing the original gun installation. The location is not known, but the aeroplanes faintly discernible in the background are B.E.2cs.
(JM Bruce/GS Leslie)

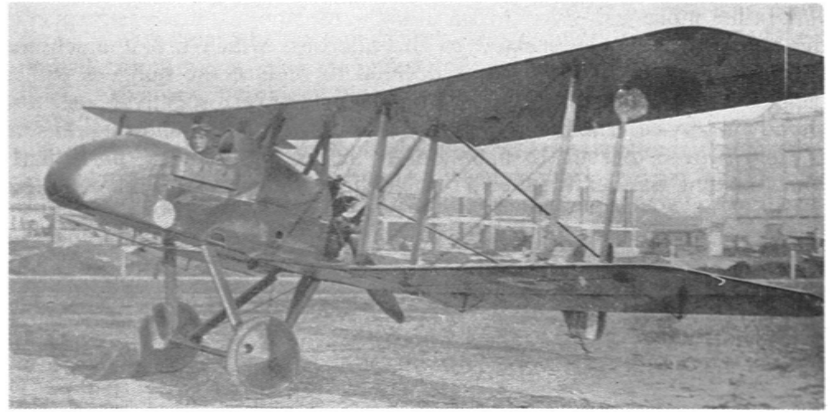
The first prototype, 7456, made a brief initial flight on 15 October 1915, before any armament was fitted. Its pilot on that occasion was Frank Goodden, who was entirely satisfied with the new scout. Four days later he took it up for an hour and a half, exploring its handling characteristics to the full.

By early November 7456 had been equipped with a Lewis machine gun pointing through an opening in the extreme nose, and capable of being swivelled through an arc of up to 30° in any direction via a linkage connected to the pilot's sighting device. On 8 November it was flown to the Central Flying School at Upavon for service trials. The school's report was most favourable, describing it as manoeuvrable, easy to land, and possessing excellent stability. The gun installation found less favour because it was inaccessible and unnecessarily complex. It was thought simpler merely to fix the gun and aim the whole aeroplane at the enemy. A week later the F.E.8 was returned to the Factory by the famous prewar display pilot B C Hucks, who had the great misfortune to crash-land and damage it beyond economical repair. The engine, which was undamaged, was removed for use in the second prototype, 7457, which was already under construction and which first flew on 19 December, piloted by Frank Goodden.

Trenchard considered its 2¼hr endurance to be insufficient, and it was therefore decided to increase the fuel tankage from 24 to 29 gallons. The gun mounting, which had been widely criticised, was changed to a fixed position on the cockpit rim, similar to that of the D.H.2. Wooden racks were provided on the cockpit sides for spare ammunition drums. These modifications were incorporated in production machines, the first order for which had been placed with the Darracq Motor Engineering Company on 11 October, four days before the type's first flight.

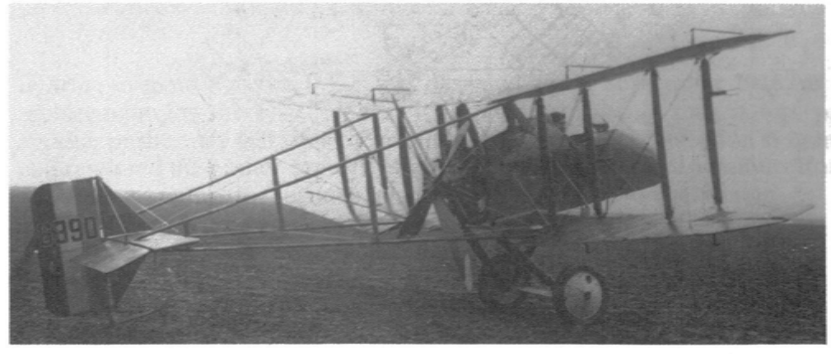
To forestall any possible problems, should supplies of the Gnome Monosoupape prove troublesome, experimental installations were made of a 110hp Le Rhône and of a Clerget of similar power so that any difficulties in substituting these engines should be solved in advance. In practice, however, it was airframes which proved to be a problem. Deliveries were

delayed for a variety of reasons, not the least of which was the fact that this was Darracq's first venture into aircraft manufacture. Therefore it was October 1916 before a complete squadron, No 40, was in service on the Western Front, although the first six machines had been pressed into use at the beginning of August.



An unidentified production F.E.8 on Farnborough Common, with the Factory buildings in the background.
(JM Bruce/GS Leslie)

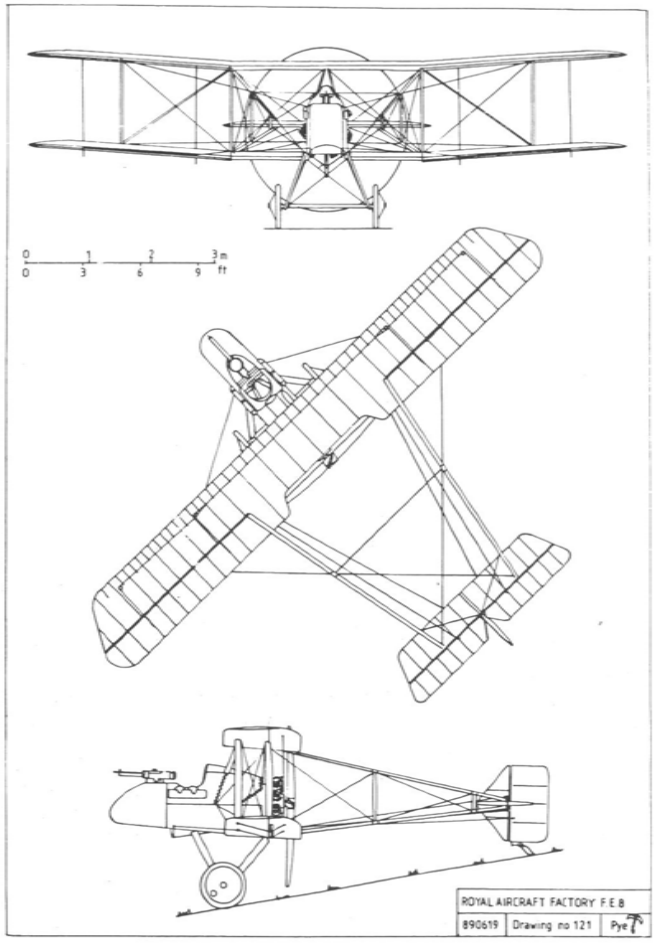
Allegations that the F.E.8 was prone to spin caused considerable concern, especially among the many recently qualified pilots whose training was, at best, somewhat basic. Therefore, during August 1916, Frank Goodden carried out a series of trials in which he deliberately spun an F.E.8 in both directions, recovering easily on each occasion by employing the standard method (centralise the controls, push the stick forwards to gain



Darracq-built F.E.8 6390. The rubber bungees which returned the ailerons into position can be seen above the upper wing.
(Military Aircraft Photographs)

airspeed, then apply opposite rudder if required). His report stated that the aeroplane was perfectly stable, and that he had only been able to initiate each spin by 'misuse' of the controls. The report, together with the story of the trials, which passed quickly down the 'grapevine' throughout the RFC, did much to stop the rumours and to restore pilots' confidence in their mounts.

A rather more justified criticism of the aeroplane was made in respect of the rubber bungees connected to the ailerons, which broke much too frequently. On 30 August it was decided to replace the bungees with a balance cable, not only on all future machines, but retrospectively on those already in service. The fuel system was also criticised by squadron pilots, as it often proved difficult to maintain the necessary pressure, particularly when the tank was nearly full. To resolve this, a small gravity tank was fitted



internally within the centre section, fed from the main tank under pressure and itself feeding directly to the engine. The D.H.2 tank was also tried, mounted externally below the upper wing centre section, but although it was streamlined it caused an unacceptable reduction in speed and the internal tank was standardised.

Later, when it was discovered that the duralumin ribs in the elevators were reacting with the dope and causing the fabric to rot, new control surfaces with steel ribs were designed. As a temporary measure while the new elevators were being manufactured, some machines were fitted with D.H.2 elevators, their hinge type and position being modified as required to make them fit.

Almost 300 F.E.8s were eventually built, and the type remained in service at least until July 1917. By that time it was long obsolete, but it enjoyed the dubious distinction of being the last pusher scout to see active service on the Western Front.

Powerplant:	100hp Gnome Monosoupape rotary
Dimensions:	
span	31ft 6in;
chord	4ft 0in;
gap	4ft 6in;
wing area	214 sq ft;
dihedral	5°;
length	23ft 0in;
height	9ft 2in.
Weights:	895lb (empty); 1,346lb (loaded)
Performance:	
max speed	94mph at sea level;
ceiling	14,500ft;
climb	9½min to 6,000ft;
endurance	2½hrs.

F.E.9

Bearing in mind that the F.E.9 was designed about September 1916, as a replacement for the F.E.2 series, it is rather surprising that it was yet another pusher. By that time the availability of gun synchronisation systems had rendered the pusher concept obsolescent, although every possible effort was made to reduce the layout's inherent disadvantages to a minimum.

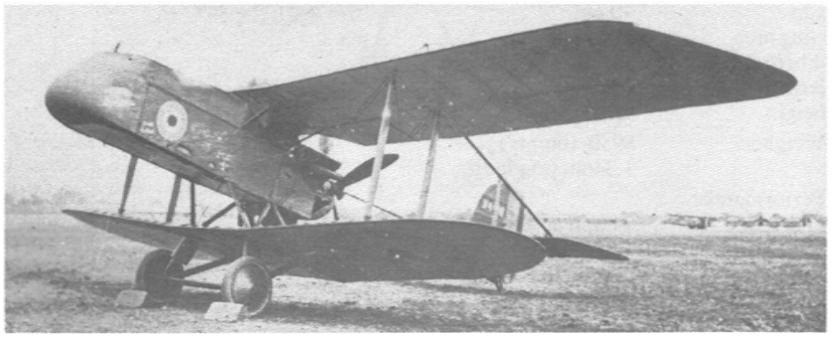
The F.E.9 was designed around the 200hp geared-drive Hispano-Suiza, and its nacelle was positioned well above the mid-gap position, to afford the observer a reasonable rearward field of fire over the upper wing without the need to resort to the acrobatics required in the F.E.2. Two Lewis guns were provided, each on a pillar mounting, one firing forwards and one to the rear. It was planned that the machine should carry a third gun for the pilot's use, mounted on the starboard side of the nacelle, but no evidence has been found that this weapon was installed. The neat undercarriage had short but

effective oleos attached to the lower centre-section, and the tailskid arrangement echoed that of the S.E.5 and R.E.8.

Dual controls were provided, those in the observer's cockpit comprising two control columns, one operating the elevators and the other controlling the rudder, as it was felt that a conventional rudder bar would obstruct the observer's freedom of movement as he performed his normal duties. Since these controls were intended only for use in an emergency, it was not considered necessary to provide any aileron controls, turns being made on rudder alone.

Steel-tube N-struts secured the nacelle to the single-bay wings, which were of unequal span, the upper-wing extensions being supported by bracing wires and inverted triangular kingposts, as was common Factory practice. Ailerons were fitted to the upper wing only, and had large horn balances, being similar to those originally fitted to the B.E.12a. As in the F.E.8, the tailbooms met at the tailplane spar. The fin was almost semi-circular, and the rudder was unbalanced.

With what, unfortunately, turned out to be misplaced confidence, a batch of twenty-four aircraft was put into production 'off the drawing board', using the Factory's own facilities.

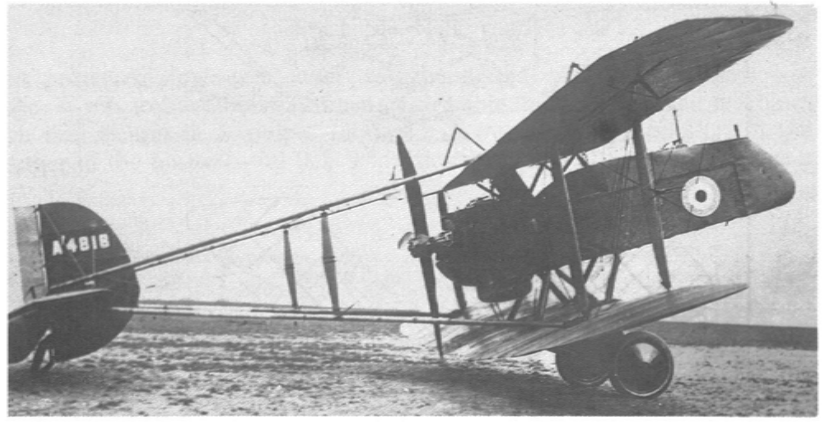


F.E.9 A4818 at Hounslow. Note the long overhang to the top wing and the huge aileron balance areas.
(Capt DS Glover via PHT Green)

The first of these, A4818, was completed by the beginning of April 1917, and test flying was undertaken by Roderic Hill, who found the rate of climb disappointing and the handling unpleasant, particularly during left-hand turns, a characteristic he attributed to the ailerons being over-balanced and the rudder being of insufficient power.

On 6 June Hill flew the aircraft to the Aircraft Depot at St Omer for service trials, apparently without any modification to its control surfaces. Lt Clark of 13 Squadron, an experienced observer who was taken up in it, reported that, from the observer's point of view, the field of fire was very good and that it was easy to fly with its odd controls. Pilots were less enthusiastic, and on 9 June Maj-Gen Trenchard reported that, although the

view was excellent, the machine itself was already a year out of date and of no use to the RFC. He recommended that experiments with the F.E.9 should be stopped, and suggested that putting the 200hp Hispano-Suiza into it was a waste of a really good engine. At this stage it appears that the nacelles had been completed for all twenty-four machines, and at least two more airframes were well advanced and were eventually completed.



Another view of F.E.9 A4818.

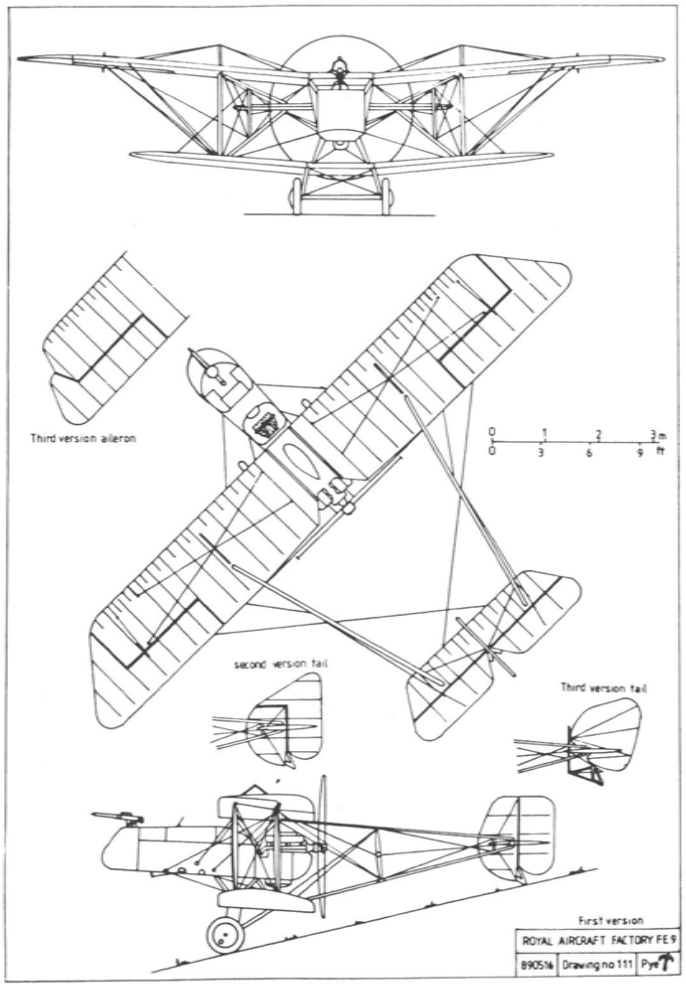
The Factory's design staff appear to have regarded the type's poor handling as a challenge to be overcome at all cost (perhaps the correct attitude to take in an aeronautical research centre), and when A4818 returned to Farnborough it underwent a lengthy series of modifications to its control surfaces. A new, high-aspect-ratio rudder of reduced area, incorporating a small horn balance, was fitted, and then the fabric was removed from the fin. Later a large balanced rudder of lower aspect ratio was substituted, without a fin. At the same time the aileron balance areas were progressively reduced.

By mid-October A4818 had been joined by the second machine, A4819, which had the high-aspect-ratio rudder and redesigned wings with two-bay interplane bracing, the outer pairs of struts being raked outwards to support the upper wing extensions and thus eliminating the need for kingposts. The ailerons had smaller horn balances than those of A4818. The second machine eventually saw service with No 78 (Home Defence) Squadron, and was written off in a landing accident at Biggin Hill the following winter.

The third and final example, A4820, which was completed ready for inspection on 1 November, also had two-bay wings. By this time a third type of aileron, with the balance area still further reduced, had been fitted to A4818 and, since this type was considered to give a marked improvement in handling, it is probable that it was also fitted to A4820.

The fates of the first and third F.E.9s are unknown, but A4820 is last recorded as undergoing engine tests in January 1918, and A4818 continued to serve as a research vehicle for investigations into aircraft control at least

until March of that year. Thereafter the F.E.9 faded into oblivion, the information obtained from its protracted development and testing being used in the design of its successors, most notably the N.E.1.

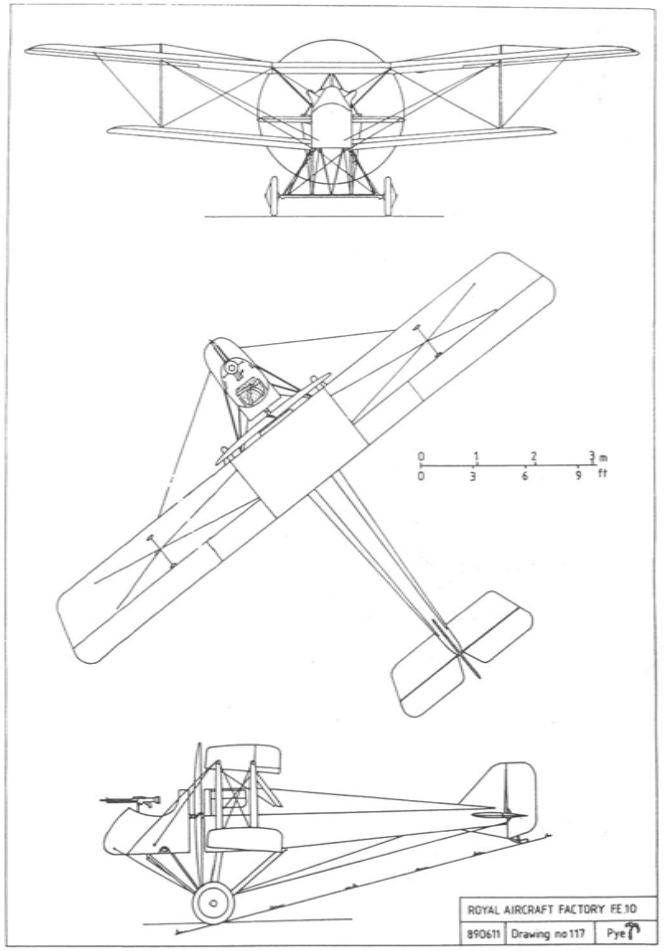


Powerplant:	200hp Hispano-Suiza V-8
Dimensions:	
span	40ft 1in (upper); 37ft 9½in (modified ailerons); 29ft 5¼in (lower);
wing area	365 sq ft;
length	28ft 3in;
height	9ft 9in.

Weight:	2,480lb (loaded).
Performance:	
max speed	105mph at sea level;
ceiling	15,500ft;
climb	5min to 3,000ft.

F.E.10

This projected single-seat scout was abandoned while still in the design stage. It was to have been a rather improbable and ill-conceived machine, with the cockpit in a 'pulpit' mounted in front of the propeller, in the manner of the unsuccessful B.E.9, presumably in an attempt to produce a



fighter with a forward-firing gun without incurring the pusher's drag penalty. The fact that it was given a designation in the F.E. series demonstrates not only the degree to which the B.E. class had been discredited, but of the difficulty in placing each and every design concept into a 'pigeon hole'.

The F.E.10 was to have been powered by the 150hp Hispano-Suiza V-8 engine, as was the S.E.5, the design of which was taking place concurrently. As the availability of gun synchronisation gears had rendered the pusher and 'pulpit' concepts out of date, and as demand for the Hispano continued to exceed supply, commonsense prevailed and the F.E.10 project was dropped in favour of the more promising tractor design. It was, however, decided that the F.E.10's vertical tail surfaces were more pleasing than those originally designed for the S.E.5, and the latter's drawings were amended accordingly.

Dimensions
Span: 35ft 0in.

F.E.11

No record of this project has been discovered.

F.E.12

Yet another uncompleted project, this big two-seater night-fighter was designed during 1917. Many of its major components, including the undercarriage, tailbooms and centre-section, were F.E.9 components, possibly derived from the cancelled production of that machine. The nacelle was basically an F.E.9 unit with the crew positions reversed, presumably with the intention of providing the pilot with the best possible view of his intended target and also to facilitate landing at night. Like the F.E.9, it was to have been powered by the 200hp Hispano-Suiza.

Armament was to have been a Vickers rocket gun, and two searchlights were to have been fitted, one in the extreme nose and the other fixed to the gun. Power for these lights was to be provided by a wind-driven generator.

Before completion the design was modified to become the N.E.1, and is further described under that designation.

Powerplant:	200hp Hispano-Suiza V-8
Dimensions:	
span	50ft 0in;
chord	6ft 0in;
gap	5ft 6in;
wing area	550 sq ft;
dihedral	4½°;
length	28ft 1½in;

height	9ft 9in.
Weight:	2,700lb (estimate).

H.R.E.2

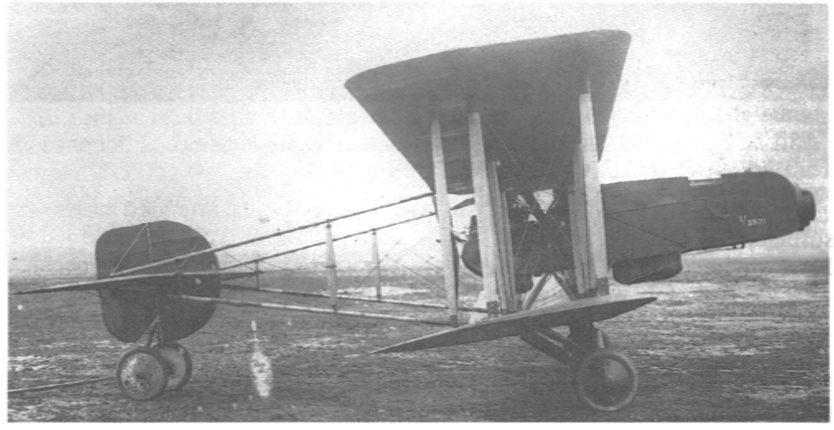
See R.E.2.

H.R.E.6

See R.E.6.

N.E.1

Developed from the F.E.12, the N.E.1, or Night-flying Experimental, employed a number of standard F.E.9/F.E.12 components, including the tailbooms, undercarriage legs, rudder and tailskid. The three-bay wings were of equal span, and had generous dihedral outboard of the centre section. Ailerons were fitted to upper and lower mainplanes. Heeding the lessons learned from the development of the F.E.9, the ailerons were plain and unbalanced. The tailbooms were parallel in plan, and followed what had become normal Factory practice by meeting at the tailplane spar, the tailplane itself being positioned on the thrust line. The elevators incorporated large horn balances, and the semi-circular fin was symmetrical about the tailplane. The undercarriage had a very wide track, the wheels being outboard of the innermost pairs of interplane struts, to facilitate landing at night. Therefore, unusually for the period, the two undercarriage legs were entirely separate, with no transverse axle. Power was provided by a 200hp Hispano-Suiza driving a four-bladed pusher propeller. The intended armament was the Vickers rocket gun or the one-pounder Coventry

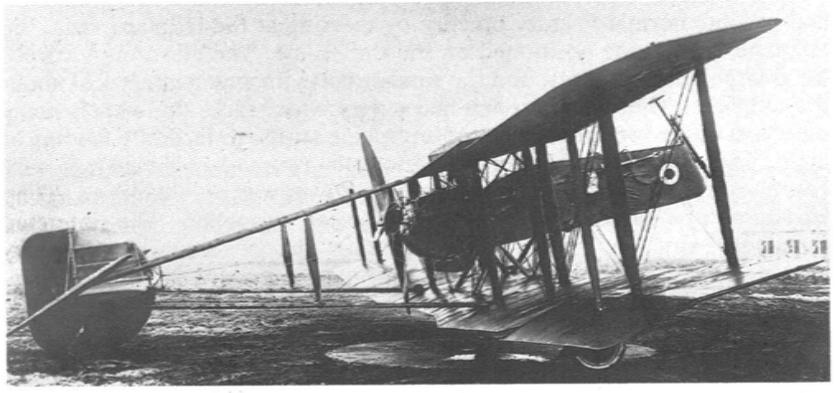


The first prototype N.E.1, showing its original nacelle and the nose-mounted searchlight. *(Imperial War Museum)*

Ordnance Works gun, with which an element within the Factory seems to have been obsessed. As in the F.E.12, a searchlight was included in the nose of the nacelle, powered by a wind-driven generator.

Six prototypes, B3971–3976, were ordered, the first of which was inspected on 3 September 1917 and made its initial flight five days later. On 14 September it was damaged, most probably in a landing accident, and the nacelle was rebuilt with the crew positions reversed, moving the pilot to the rear cockpit, where a Lewis gun was mounted on the starboard cockpit coaming for his use, in the manner suggested for the F.E.9. The searchlight was not refitted. Test flying resumed on 4 October.

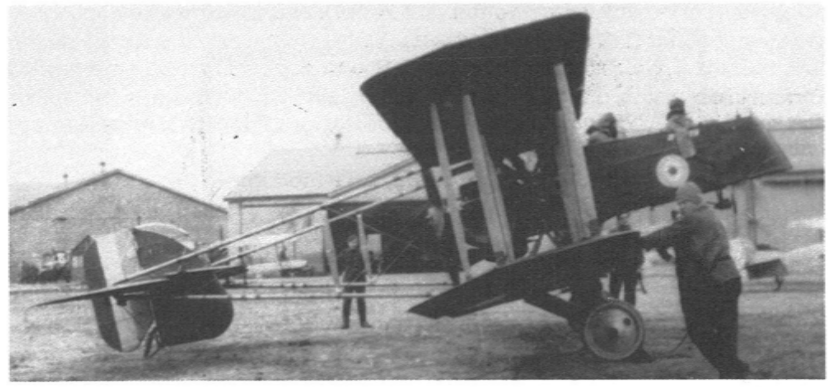
Service trials started on 6 November at Martlesham Heath, and the resulting report cast doubts upon the adequacy of the N.E.1's performance compared with that of its contemporary 'rivals'. While it was considered to be a slight improvement on the F.E.2b, which it was thought most likely to replace, and while the view from either cockpit was described as excellent, it was found to be heavy and awkward, although generally easy to fly. As the N.E.1 was neither smaller nor much better streamlined than the F.E.2b, it was hardly surprising that its performance, with similar power, was so little better.



The N.E.1 B3972 fitted with experimental armament.

The general lack of enthusiasm on the part of its intended users was sufficient to ensure that the N.E.1 did not enter volume production. Nevertheless, all six prototypes were completed, most probably because they were already well advanced. In fact the second, B3972, was completed by 14 November and, after acceptance trials, was handed over to the RFC, serving with No 78 (Home Defence) Squadron at Sutton's Farm. It is probable that this machine was built without the searchlight or rocket gun, and it may have had the modified nacelle then fitted to B3971.

A redesigned fin, with increased ventral area, was fitted to B3973, which was completed on 23 November. Early in the new year this aircraft was fitted with bomb racks under the lower centre-section, and throughout



N.E.1 B3970 with increased area to its ventral fin.
(Military Aircraft Photographs)

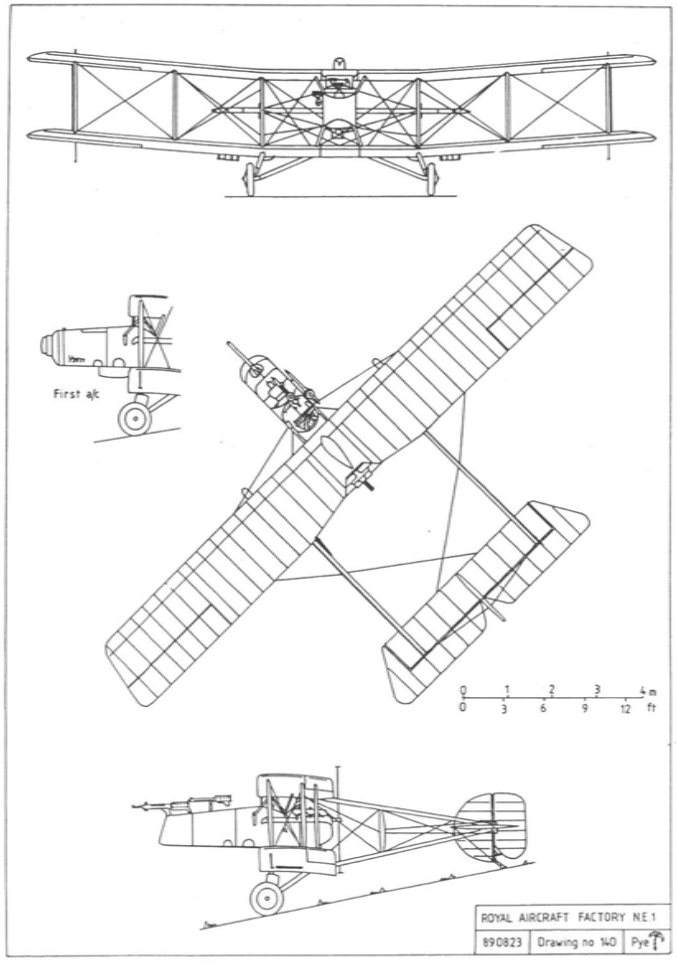
The N.E.1 B3975 during bomb-dropping trials at Orfordness. Note the bombsight fitted to the rim of the forward cockpit.
(Roy Walker)

February and March it took part in bomb-dropping trials at the experimental station at Orfordness.

The fourth prototype was not flown, being used exclusively for static experiments, and may eventually have been tested to destruction. The fifth example, B3975, was completed late in December 1917 and flown by the experimental station at Orfordness and at the Isle of Grain, but for what purpose is not known. Although the final machine, B3976, was completed, it was never fitted with its engine and obviously was not flown.

Powerplant:	200hp Hispano-Suiza V-8
Dimensions:	
span	47ft 10½in;
chord	6ft 0in;
gap	5ft 5½in;
wing area	555 sq ft;
dihedral	4½°;
length	28ft 6in (30ft 2in with searchlight);

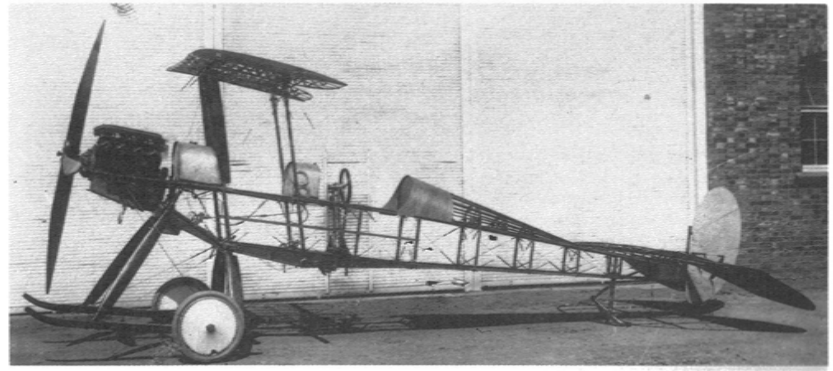
height	10ft 0in.
Weights:	2,071lb (empty)
	2,946lb (loaded).
Performance:	
max speed	95mph at sea level;
ceiling	17,500ft.



R.E.1

The design of this neat and attractive two-seat tractor biplane appears to have been something of a joint effort, with Geoffrey de Havilland, Henry Folland and Edward Busk each having some involvement. It might have

been begun under the designation B.S.2, although this was soon changed to Reconnaissance Experimental No 2, clearly indicating its intended purpose. Although its derivation from the B.E.2 was obvious, it was a smaller and more refined machine, its rôle requiring it to carry no more load than its crew and sufficient fuel for its mission.



The R.E.1 fuselage before covering.
(Military Aircraft Photographs)

The staggered single-bay wings had warping for lateral control, and used a recently developed aerofoil section which allowed a greater depth of rear spar, eliminating a weakness discovered in tests upon the B.E.2. The fuselage structure made some use of steel tube, was fabric covered, and had deep coamings giving well-protected cockpits. A triangular fin was fitted, together with a rudder of similar shape to that of the B.E.2, and the undercarriage employed only four struts, two fewer than in the earlier aeroplane. Neat aluminium cowlings enclosed the 70hp Renault engine, which drove a four-bladed propeller. To facilitate transport by road, the

The R.E.1 in flight, with short-span warping wings.
(Royal Aerospace Establishment)

wings could easily be removed and strapped to the fuselage sides.

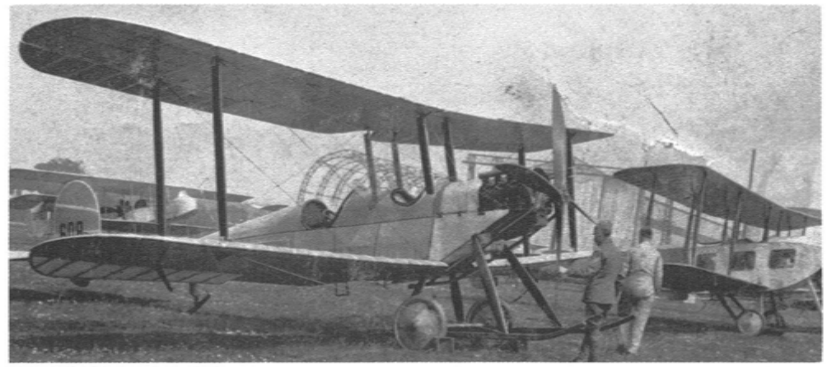
A large wheel on the control column operated the wing-warping mechanism, one of the machine's less successful innovations being the incorporation of the engine controls within the centre of this wheel.

The first R.E.1 following its modification to include ailerons.
(Military Aircraft Photographs)

Two R.E.1s were built, the first, which became 607, being completed during May 1913. Following its initial flight tests it was used by Busk for a lengthy programme of development and test flying in connection with his investigations into inherent stability. Over a period of some months the dihedral angle was progressively increased from one degree to something in excess of three degrees. The fin area was reduced, that of the rudder increased, and a new tailplane of rectangular planform substituted for the original. These modifications gave longitudinal stability, but lateral stability proved impossible to achieve with warping wings, as their tendency to self-warp in gusts was too great. New wings incorporating ailerons were therefore fitted, and were rigged with their stagger reduced by four inches.

On 25 November 1913 Busk was able to fly the machine for seven miles without touching the aileron control, relying on the dihedral to right the aeroplane in a gust. Turns were made on rudder alone, the machine automatically taking up the appropriate angle of bank.

The second R.E.1 was completed by September 1913, and was allotted the serial 608. It differed from its predecessor in several ways; the fuselage was longer, the rudder included a curved balance area forward of the rudder post, and there was no fin. Later, four small rounded fins were fitted on the upper wing, one above each pair of interplane and centre-section struts. These were removed when new wings of increased span and incorporating ailerons were fitted early in 1914. In this form 608 was handed over to the RFC, which gave it the serial 362 on 6 March 1914, only to revert to 608 ten



R.E.1 608 with new wings, incorporating ailerons, photographed on Jersey Brow in company with a Sopwith three-seater and a Farman.
(JM Bruce/GS Leslie)

days later without the new number appearing on the machine.

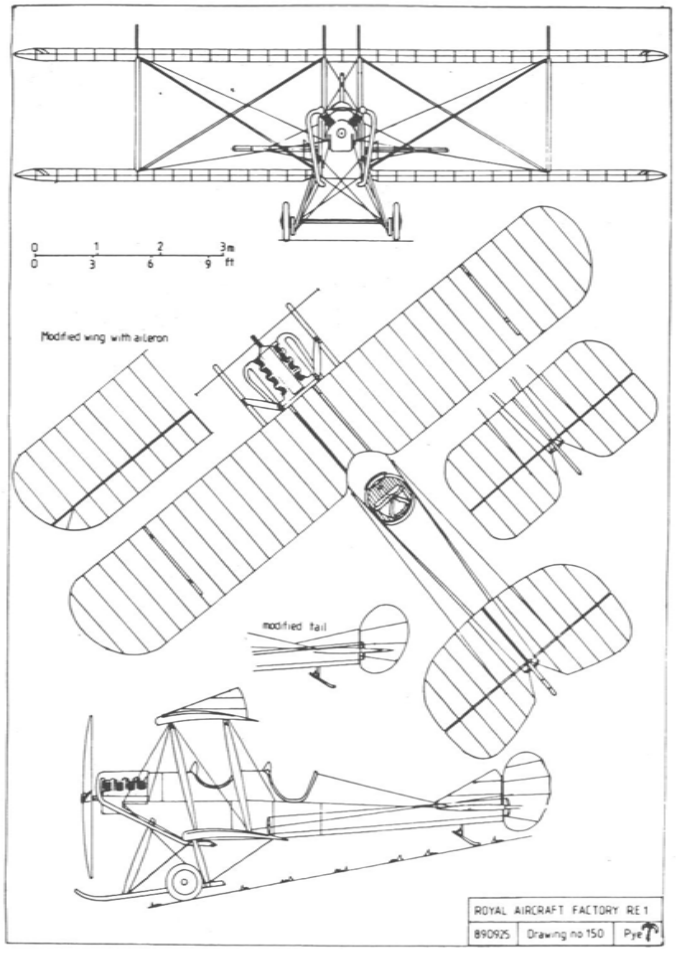
The aircraft was used by 6 Squadron up to the outbreak of the war, when it was reallocated to 2 Squadron to help bring the unit up to strength before it flew to France with the Expeditionary Force. On 1 September 608 suffered engine failure and was wrecked in the resulting forced landing.

The first R.E.1 remained at Farnborough throughout its life, its stability making it ideal for testing various devices whose operation occupied much of the pilot's attention, most of them being connected with aerial photography or wireless transmission. It is not clear how many of the numerous modifications made to 607 throughout its life were designed to assist in achieving stability, and how many may have been intended to assess their effect upon what was already an inherently stable aeroplane.

In the original design provision had been made for the installation of 1mm-thick armour plate on the forward fuselage, to afford the engine, fuel tank, and crew at least some protection against small-arms fire from the ground. This armour, which was to be made detachable, appears to have been fabricated during June/July 1913. Surviving records do not indicate to which machine it was actually fitted, how effective it might have been, or if and when the aeroplane was flown with it in place. However, its additional weight does suggest a logical explanation for the later increase in wingspan.

The eventual fate of 607 is unknown, the last confirmed report of its existence being in February 1915, when it was still flying at Farnborough.

Powerplant:	70hp Renault V-8
Dimensions:	
span	34ft 0in (later 36ft 0in);
chord	5ft 6in;
wing area	316 sq ft.
Weights:	1,000lb (empty) 1,580lb (loaded).

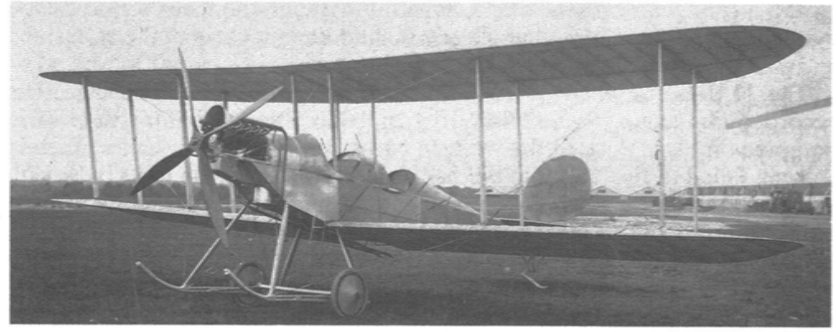


Performance:

max speed	78mph at sea level;
stalling speed	48mph;
initial climb	600ft/min.

R.E.2

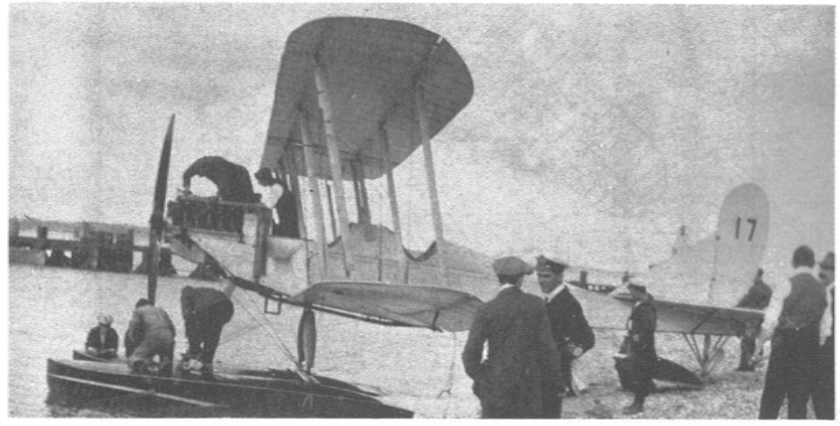
A two-seat reconnaissance aeroplane, the R.E.2 clearly had roots in the R.E.1 and the B.E. series. It had two-bay wings with moderate forward stagger, lateral control being achieved by warping. The low-aspect-ratio



The R.E.2 as originally built, with B.E.3-type rudder and 70hp Renault engine.
(Royal Aerospace Establishment)

rudder was aerodynamically balanced, and bore a marked resemblance to that of the B.E.3. There was no fin and, since there was no need to make allowance for the high-mounted rudder, the elevator was in one piece. Power was provided by a 70hp Renault engine, and the original undercarriage was similar to that of the R.E.1.

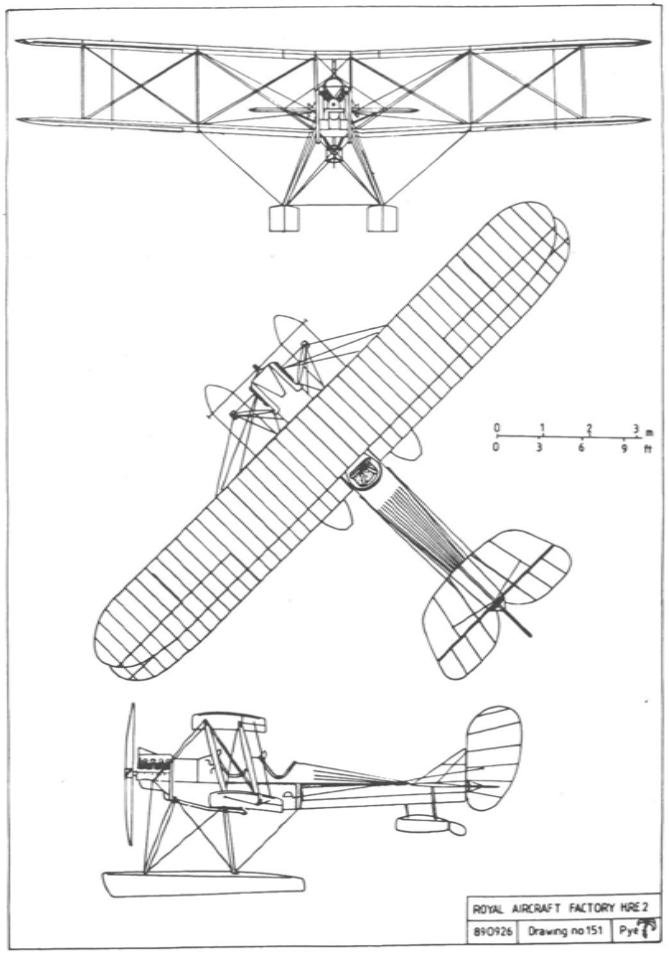
The R.E.2 made its initial flight on 1 July 1913 and, following satisfactory trials, it was converted into a seaplane—or 'hydro-aeroplane' in contemporary parlance—by replacing the wheels with floats and fitting an additional small float, incorporating a water rudder, under the tail. These floats differed from those hitherto fitted to Factory aeroplanes in having stepped undersides designed to help break the adhesion of the water, and represented one of the earliest uses of this type of float. In this form the machine was known as the H.R.E.2 (Hydro-Reconnaissance Experimental). To offset the additional forward keel area created by the



The H.R.E.2 with a 100hp Renault engine undergoes flotation trials.
(JM Bruce/GS Leslie)

floats, a triangular fin was added, together with an unbalanced B.E.2-type rudder, this being mounted unusually high to keep it clear of the water and to avoid the need to modify the existing elevator.

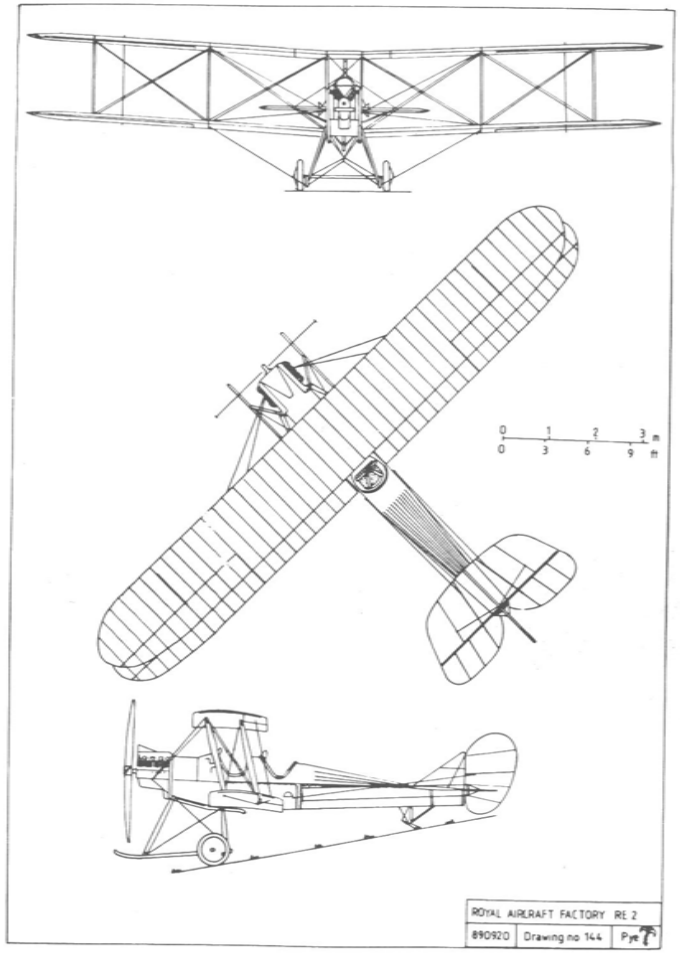
The H.R.E.2 appears to have been underpowered, as no take-off is recorded. Its engine was replaced by a 100hp Renault before tests were resumed on Fleet Pond at the western end of Laffan's Plain. Unfortunately it again failed to rise, ran into the bank, and turned over on to its back with consequent damage to the floats and rudder. No further attempts to fly it from water appear to have been made, and during repair it was converted back to its wheeled undercarriage, the modified vertical tail and the 100hp engine being retained. In this form it reverted to the designation R.E.2, and was handed over to the Admiralty to replace an Avro biplane which had



previously been equipped with floats by Commander Oliver Schwann RN, and which, following an accident, had ended up at Farnborough for repair. The fate of the Avro is not recorded, and so tenuous is its connection with its replacement that even O'Gorman seems to have become confused as to which machine was meant to fill that rôle. On at least one occasion he refers, in his private diary, to the R.E.3 as being in lieu of 'Schwann's Avro'.

The R.E.2 served with the RFC's naval wing (later the RNAS), and was given the serial 17.

At some time about November 1914 it was returned to the Factory and fitted with new wings incorporating ailerons, as designed for the R.E.5. It crashed on 10 February 1915 and was not repaired.



Powerplant:	70hp Renault V-8; 100hp Renault V-12
Dimensions:	
span	45ft 3½in;
chord	6ft 0in;
gap	6ft 3½in;
length	32ft 3in;
height	12ft 2in;
stagger	1ft 7in;
dihedral	2°;
incidence	4½°;
wing area	498 sq ft.
Performance:	
max speed	(70hp) 60mph at sea level; (100hp) 75mph at sea level;
climb	5min to 3,000ft;
endurance:	4½hrs.

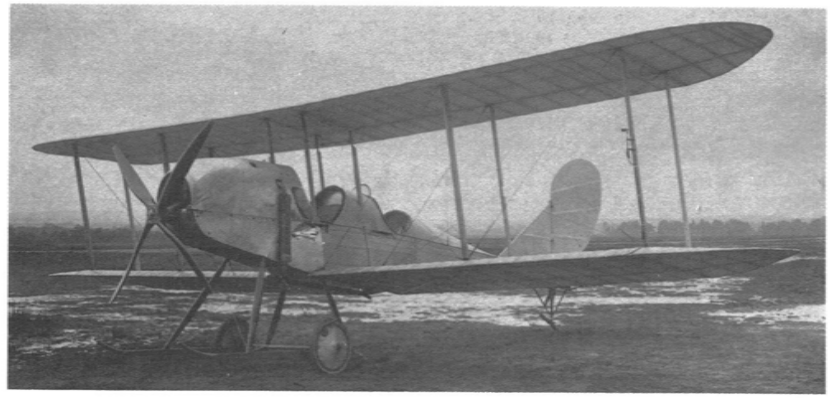
R.E.3

Completed in November 1913, the R.E.3 was very similar to the penultimate version of the R.E.2, having warping wings, a wheeled undercarriage, a one-piece elevator, and vertical tail surfaces identical to those of its predecessor. The major difference was in the forward fuselage, which was deepened to accommodate the extra height of the 120hp six-cylinder Austro-Daimler engine.

The R.E.3 at Farnborough. Its similarity to the final form of the R.E.2 is obvious.
(JM Bruce/GS Leslie)

Although O'Gorman, in his private diary, once identified it as the replacement for Schwann's Avro seaplane, this was almost certainly a confused reference to the R.E.2, for the R.E.3 was clearly intended as a two-seat reconnaissance aeroplane for Army use, paving the way to the R.E.5.

Its career was cut short when, on 27 September 1914, it suffered engine



The R.E.3, showing the deep cowling needed to enclose its 120hp Austro-Daimler engine.
(JM Bruce/GS Leslie)

failure and crashed while flying over Farnborough Common, fortunately without injury to its pilot, E T Busk. Already superseded by the R.E.5, it was deemed to have served its purpose and was not repaired.

Powerplant:	120hp six-cylinder Austro-Daimler
Dimensions:	
span	45ft 3½in;
chord	6ft 0in;
gap	6ft 3½in;
length	32ft 3in;
height	12ft 2in;
wing area	498 sq ft.

R.E.4

The R.E.4 was designed to descend steeply so that it could land in fields surrounded by trees, for reconnaissance on active service. It is referred to in O'Gorman's diary as his 'out of field machine'.

It would presumably have been a continuation of the R.E.2/R.E.3 series, being a two-seater with unequal-span wings, powered by a 120hp Austro-Daimler.

No drawings survive, and there is no evidence that it was built.

R.E.5

Developed from the R.E.2 and R.E.3, this sturdy two-seater was designed towards the end of 1913 and shared many details with the earlier machines. The two-bay wings had ailerons on upper and lower mainplanes and, as in earlier R.E. types, the fuselage frame made some use of steel-tube construction. Power was again provided by the 120hp water-cooled

An early R.E.5 with equal-span wings.
(Military Aircraft Photographs)

Austro-Daimler engine. The triangular fin was a legacy from the earlier designs, but the unbalanced rudder was of a new shape, and was attached to the sternpost at a lower level than on its predecessors, the elevators being divided to accommodate it.

Because the R.E.5 was not a wholly new design, but a step in a steady development, and appeared to fill an operational requirement exactly, the War Office obviously felt justified in ordering it into production 'off the drawing board'. Construction of a batch of twenty-four was therefore put in hand at the Factory, their cost nominally being taken from the £25,000 provided by the Admiralty in exchange for the Army's airships, which were to be transferred to the Navy on 1 January 1914.

The first R.E.5 was completed, ready for inspection, by 26 January, and three more were completed the following month. The fifth and sixth examples, delivered in March, had long extensions to the upper wing, supported by additional interplane struts inclined steeply outwards, and

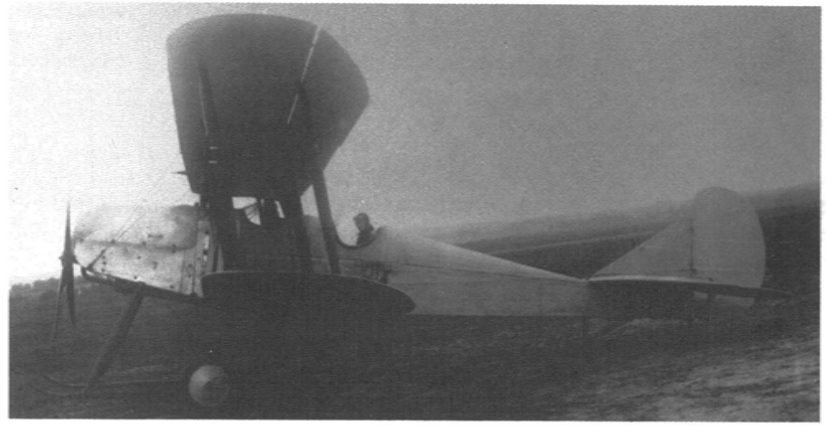
An R.E.5 with the long-span upper wing. One of the officers by the wingtip appears, from his uniform, to be French.
(Military Aircraft Photographs)

Norman Spratt about to take off in an R.E.5 to break the altitude record, 16 January 1914.
(Royal Aerospace Establishment)

appear to have been built as single-seaters. A Factory test pilot, Norman Spratt, took aircraft 380 to an altitude of 18,900ft on 14 May, a feat which, following the machine's handover, service pilots spent much of the summer trying to emulate. Capt J H W Becke, the CO of 6 Squadron, reached over 17,000ft in June.

At least two more examples, the twelfth and thirteenth produced, had the extended upper wing, together with increased fuel tank capacity to extend their range.

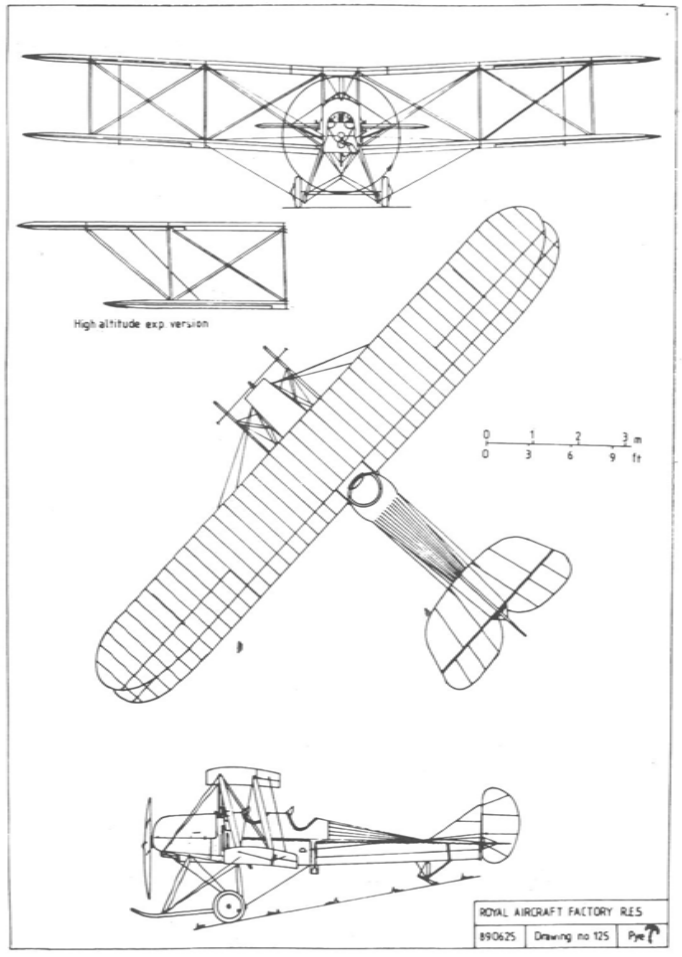
Problems with the Austro-Daimler engines delayed production, and later examples were fitted with Beardmore-built engines which incorporated a



An unidentified R.E.5 at Farnborough on 17 July 1914.

number of modifications to the Austro-Daimler design, including modified crankshafts. Although at least fifteen machines had been completed by the outbreak of war, the last of the twenty-four were not completed until early in 1915.

Active service revealed that the R.E.5's landing run was rather too long for many of the makeshift aerodromes adopted by the RFC in France, and experiments were made with a 'plough brake', which was fitted to the undercarriage and lowered on landing to reduce the run. This may also have been the reason that experiments were carried out with airbrakes. These comprised flat plates which normally lay against the fuselage sides near to the louvres which allowed airflow through the internal radiator, and were hinged so as to project at right angles to the airflow when required. These airbrakes were also fitted to many R.E.7s.



No further R.E.5s were built once the original production run of twenty-four had been completed. The majority of these served with the RFC either in France or with training squadrons, but one found its way to the RNAS. Another was retained at Farnborough for experimental purposes, eventually being written off while engaged in experiments in the lifting and release of heavy weights, as part of an investigation designed to ascertain what bomb loads might safely be carried in the future.

During 1915 the Factory fitted an R.E.5 with an oleo undercarriage of the type later adopted for the R.E.7. The same machine was also given a pre-production R.A.F.4 V-12 engine with an exhaust manifold similar to that later adopted for the B.E.12. An enlarged fin, with a curved leading edge, was also fitted to this machine.

On 31 July 1915 Capt J A Liddell of 7 Squadron was flying an R.E.5 on a bombing mission, and was badly hurt when it was hit by anti-aircraft fire, which also smashed the top of his control column. Despite his injuries he succeeded in returning the damaged machine to the British side of the lines, thereby saving the life of his observer. He was awarded the Victoria Cross for his courage, but died of his wounds some weeks later.

One R.E.5 which was brought down behind the enemy lines was recovered intact and exhibited in Germany, together with other captured Allied weaponry.

Towards the end of 1915 the R.E.5s were gradually withdrawn from active service, the last machine returning from France early the following year, but they continued to serve with training establishments until they were written off.

Powerplant:	120hp Austro-Daimler or Beardmore
Dimensions:	
span	45ft 3½in (57ft 2½in with extensions);
chord	6ft 0in;
wing area	498 sq ft (569 sq ft with extensions);
Performance:	
max speed	78mph at sea level;
initial climb	400ft/min.

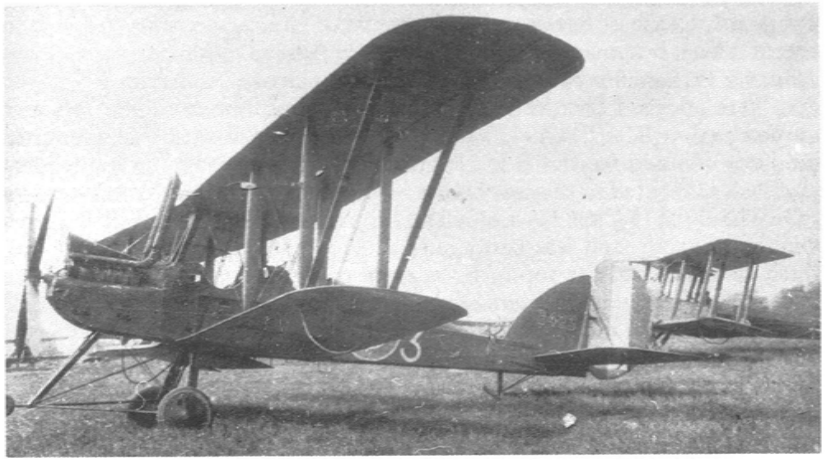
R.E.6

This 1914 design was for a three-seat biplane powered by a 250hp engine and fitted with a float undercarriage, possibly similar to that of the H.R.E.2. The project was abandoned before the design had been completed, and only a handful of component drawings survive.

R.E.7

Strictly speaking there was no prototype for the R.E.7, although the modified form of the R.E.5, with extensions to the upper wing, can possibly be regarded as having fulfilled that rôle. In fact, the design was briefly

known as the R.E.5a before being redesignated R.E.7. The broad span of its wings endowed it with weight-lifting abilities which caused it to be regarded as worthy of volume production, and 233 were eventually ordered from various subcontractors.



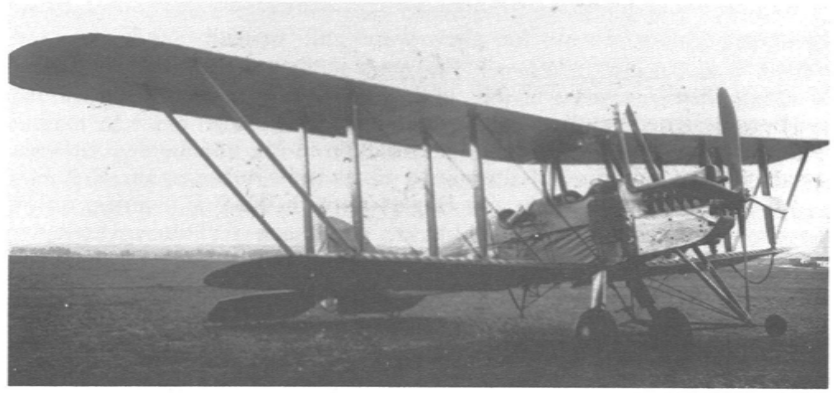
R.E.7 2423 at South Carlton. The aircraft behind the rudder is a D.H.6.
(PHT Green)

As in the R.E.5, the forward fuselage was of steel tube, becoming a more conventional wire-braced wooden structure aft of the rear cockpit. The oleo undercarriage, which had a small buffer nosewheel, was similar to that of the early F.E.2b, and the airbrakes which had been tested on the R.E.5 were included, with the aim of reducing the landing run. The 120hp Beardmore engine, a licence-built Austro-Daimler, was again adopted, together with the concealed radiator previously designed for use in the R.E.5.

The production R.E.7 differed from the modified R.E.5 in several ways, being fitted with a new tailplane of higher aspect ratio and having a revised wing structure which eliminated the centre-section, the upper wing panels meeting above the fuselage centreline, where they were supported by inverted-vee cabane struts. The wingtip shape was modified to a semi-circular planform, rather than the elliptical shape of the earlier design. The interplane struts were of a broad streamlined shape, their ends tapered in accordance with a formula established by W H Barling and H A Webb which eventually became standardised for strut design.

A mounting was provided beneath the cockpits to carry the 336lb bomb, which had itself been designed at the Factory, but, as was common at the time, no provision was made for any other armament.

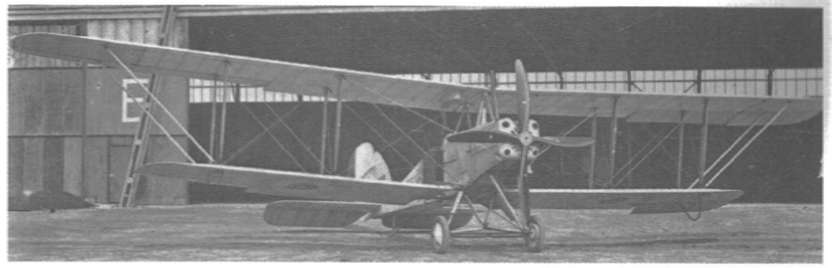
Delivery of completed machines began in July 1915 and, following flight testing, the first example reached a front-line squadron in France by late the following September.



An unidentified R.E.7, showing the installation of its R.A.F.4a engine. Note the hinged airbrakes beside the forward cockpit.
(Military Aircraft Photographs)

The R.E.7's service career was destined to be brief and undistinguished. Not only was the observer in the front cockpit, surrounded by struts and wires, unable to operate any effective armament, but the type was very seriously underpowered. Engineers at the Royal Aircraft Factory announced on 21 January 1916 that an increase in power of approximately five per cent could be obtained by the removal of the silencers and the substitution of stub exhausts. While this was useful when considered as pure research, it did little to improve the performance of the R.E.7, and the War Office was, quite understandably, unimpressed.

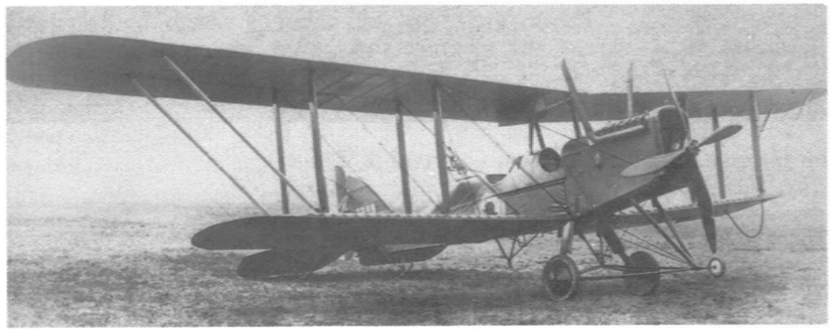
By March, Trenchard considered the R.E.7 to be so outclassed as to be 'useless', and he requested its immediate replacement. At that time, however, there was simply nothing better available, although the following month saw the first delivery of machines powered by the 140hp R.A.F.4a engine, copying an experimental installation made in the R.E.5 the previous summer. This engine, being both slightly more powerful and lighter than the Beardmore, gave a marked improvement in climb, although the top speed was little better. Difficulties with lubrication in the early production engines



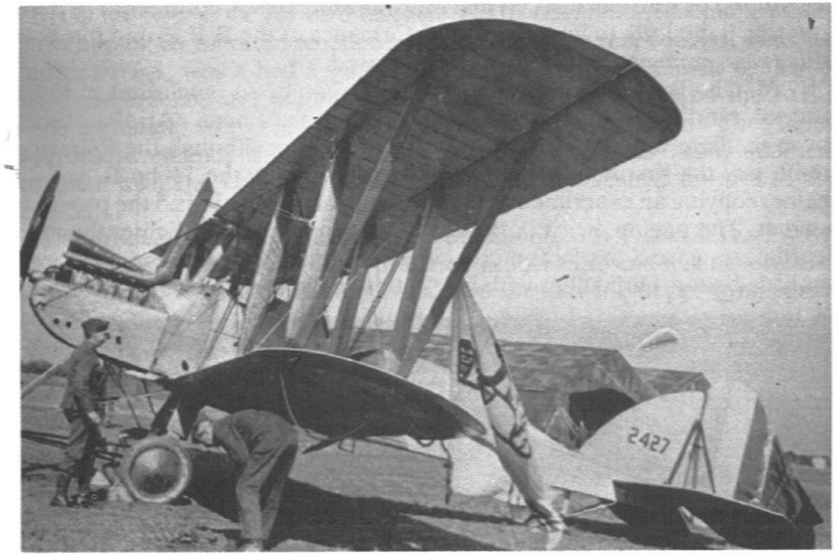
An R.E.7 fitted with a 225hp Sunbeam Maori engine in an elaborate cowling.
(JM Bruce/GS Leslie)

limited their reliability, and the aeroplanes thus powered soon met with Trenchard's disapproval, for they were still woefully underpowered. However, as was often the case at that stage in the war, the RFC simply had to accept whatever was available, and await the arrival of new types which had been designed in full knowledge of the needs of war.

Nevertheless, the Farnborough staff laboured on, making experimental installations of a number of alternative power units including the R.A.F.3a and the Rolls-Royce Falcon and Eagle. As with the F.E.2 series, only a massive increase in power could bring about any real improvement in



R.E.7 2399 with a Rolls-Royce Falcon engine and a third, gunner's cockpit.
(PHT Green)

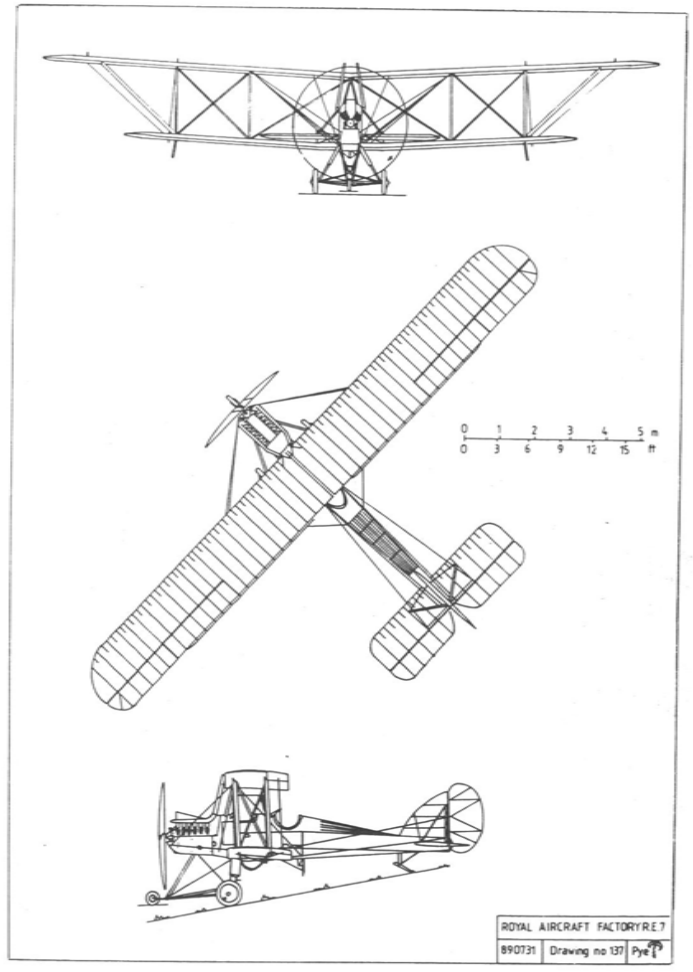


R.E.7 2427 in service as a target tug. The actual target, a crude drawing of an aeroplane fuselage, can be seen behind the port outer interplane struts.
(JM Bruce/GS Leslie)

performance, and the few engines capable of providing such power were needed for newer designs.

The R.E.7's lack of effective defensive armament, which was as great a handicap as its poor performance, was rather more easily resolved. A number of them had a third cockpit, complete with a Nieuport gun ring, installed behind the pilot. The first of these three-seaters, 2348, was completed and ready for trials by 26 September 1916, and had a 160hp Beardmore engine in lieu of the 120hp unit previously installed. Another benefited from the provision of a Rolls-Royce Eagle, and proved quite useful before it was written off in a crash on 31 January 1917.

Despite these various improvements the R.E.7 was still not really suitable for front-line service, and its withdrawal began in mid-1916, although it



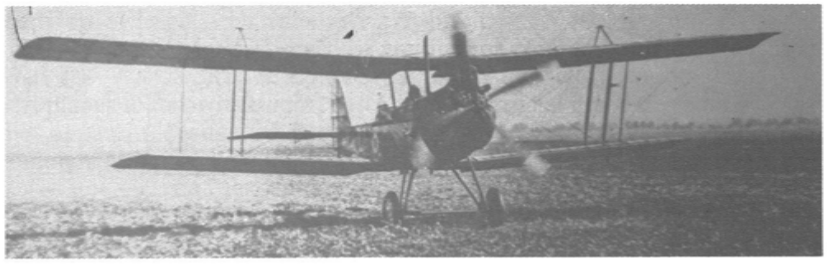
served with training establishments virtually until the end of the war.

A rôle in which the type finally found a niche was that of target tug, it being one of the first machines employed for this purpose, towing a cloth sleeve against which trainee aircrew could practise aerial gunnery.

Powerplant:	120hp Beardmore; 140hp R.A.F.4a V-12; 250hp Rolls-Royce Eagle V-12
Dimensions:	
span	57ft 2in (upper); 42ft 0in (lower);
chord	6ft 0in;
gap	6ft 6in;
wing area	548 sq ft;
stagger	3in (11in with Rolls-Royce Eagle);
length	31ft 10½in;
height	12ft 7in.
Weights	
(Beardmore):	2,170lb (empty); 3,290lb (loaded)
(R.A.F.4a):	2,140lb (empty); 3,349lb (loaded)
(R.R. Eagle):	2,702lb (empty); 4,109lb (loaded)
Performance (Beardmore):	
max speed	82mph at sea level;
ceiling	6,500ft;
climb	30½min to 5,000ft.

R.E.8

Design work on this general-purpose two-seater, which was conceived as a replacement for the obsolescent B.E.2c, started late in 1915, the drawings being finalised early the following year. It owed little or nothing to any previous R.E. type, except perhaps that the powerplant was the R.A.F.4a, the lubrication problems of which were now believed to be solved. As the wings and tailplane of the new design were virtually identical with those of the B.E.2e, it is not unreasonable to suggest that the designation R.E.8 was deliberately chosen to avoid any prejudice which may have been caused by

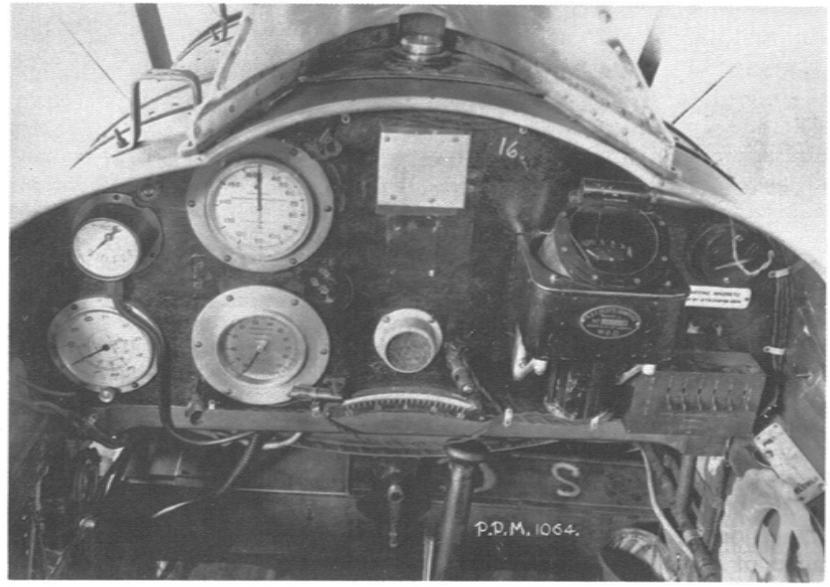


An unidentified R.E.8 taking off from a large, level and luxuriantly grassed field.

placing it within the now discredited B.E. series where it really belonged.

The fuselage was a conventional wire-braced wooden structure, the cross-sectional area of the aft end being kept as small as possible to reduce the vulnerable 'blind spot' and to increase the observer's field of fire. The engine was mounted to give downthrust which, together with the mainplanes' generous angle of incidence, would reduce the landing run, obviating the need for the airbrake which had been a feature of earlier designs. This inclination, visually exaggerated by the scoop which admitted cooling air to the engine, gave the machine a somewhat 'broken-backed' appearance which was not immediately attractive.

Rudimentary dual control was provided in the rear cockpit, but was arranged so as not to interfere with the observer's normal duties. His control column, which operated the elevators only, was on the starboard side, convenient to his right hand, and was normally clipped to the fuselage framework when not in use. On the port side of the cockpit there was a conventional throttle, below which was a hand grip attached to the rudder cables.



An R.E.8 pilot's 'office', including a Royal Aircraft Factory-pattern compass. Layouts varied slightly between manufacturers, but all machines were similarly equipped. *(JM Bruce/GS Leslie)*

The pilot's instrument panel included only a compass, an oil pressure gauge, a revolution counter, an airspeed indicator, an altimeter, a clinometer and a watch. The tailplane incidence could be adjusted by a wheel in the pilot's cockpit to trim the aeroplane, which could be made to

fly 'hands-off', the inherent stability beloved by Farnborough's designers being provided by generous lateral and longitudinal dihedral. To offset the machine's normal tendency to turn slowly to the right as a torque reaction to the rotation of the propeller, a rubber cord was attached to the rudder bar, its tension being adjustable via a Bowden-type lever. This relieved the pilot of the need to apply constant foot pressure to keep the machine on a straight course.

The rudder was of high aspect ratio and adequate area, but the fin, although of generous proportions in the preliminary layout drawings, was reduced in size in the final design and appears, in hindsight, to have been dangerously small.

The initial design work was completed before any gun synchronisation system became available, and preliminary drawings* included provision for a fixed forward-firing Lewis gun, deflector blocks being attached to the propeller blades to prevent damage. The R.E.8 was equipped with a mounting for a Thornton Pickard camera.

An early R.E.8 with a pillar mounting for the observer's Lewis gun. Later machines were fitted with the Scarff-ring mounting.
(JM Bruce/GS Leslie)

Two prototypes, 7996 and 7997, were built, the former taking to the air for the first time on 17 June 1916, piloted by Frank Goodden. The second machine made its first flight on 5 July, and on the 16th Goodden flew it to France for the all-important service trials. It was tested by an unusually wide range of personnel, ranging from Gen Brooke-Popham to pilots from front-line squadrons, and although a number of small details were criticised, all reported favourably. Brooke-Popham was particularly impressed by its speed range, but insisted that its offensive armament should be a belt-fed Vickers gun, not the Lewis as originally planned.

The necessary modifications were speedily incorporated into the drawings, and into the batch of approximately fifty machines already under construction in the Farnborough workshops. Within a matter of weeks

* No. A9429, PRO reference AVIA 14/14/1.

Immaculate Daimler-built R.E.8 C2298. Note the wheel chocks and the screw pickets beneath the wings.

production orders for over a thousand more had been placed with numerous contractors.

The engine's air scoop made it nearly impossible to mount the Vickers gun in the usual position, on the cockpit coaming immediately in front of the pilot, and several alternative locations were tried before an external mounting low on the port side of the fuselage was adopted as standard. The Vickers-Challenger interrupter gear used in early installations was later replaced by the hydraulically operated Constantinesco gear, and the far more effective Scarff ring eventually replaced the simple pillar mounting which originally carried the observer's Lewis gun.

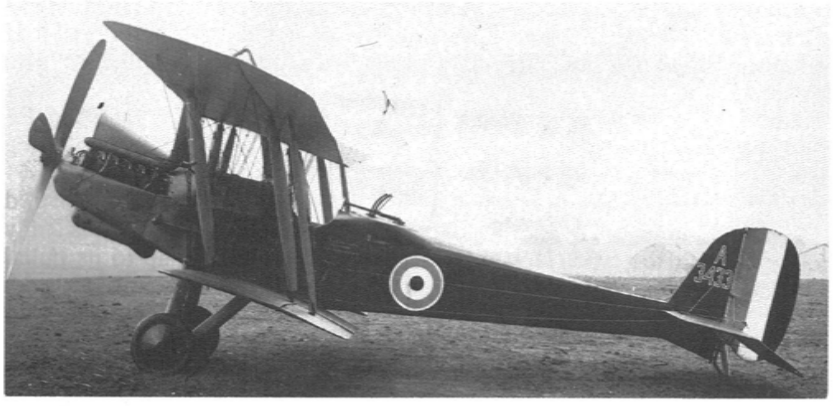
The first, Royal Aircraft Factory-built, production R.E.8 was completed by 13 September 1916, and by November 52 Squadron had been fully equipped with the type. However, it appeared not to live up to its initial promise, and the squadron's pilots encountered difficulties both with the engine, which was still not totally free of its earlier problems, and with involuntary spins. Totally disillusioned with the new machines, they were allowed in January 1917 to exchange their R.E.8s for the B.E.2es then being operated by 34 Squadron, whose much more experienced pilots were considered better able to cope with the R.E.8's alleged 'trickiness'. Maj J A Chamier, who was on the staff of the Third (Corps) Wing, to which both squadrons belonged, prepared the following notes for the guidance of pilots, describing the characteristics and handling of the R.E.8:

> . . . the chief thing to remember is that the machine gives very little indication of losing its speed until it suddenly shows an uncontrollable tendency to dive which cannot be corrected in time if you are near the ground . . .
>
> You will find that the rudder control in every case of spinning or swinging tail will become very stiff, and you may not be able to get it very central but you should aim (without putting on sufficient pressure to break anything) to do this.

With the engine off the only thing is to avoid gliding too slowly . . . at 65mph or below, when gliding, the machine suddenly loses speed. This is particularly the case when making a turn to enter the aerodrome as the extra resistance caused by the rudder is sufficient to bring down the pace . . .

One more point as regards losing speed. Observers must be cautioned that when an aeroplane is gliding down from work over the lines they must not stand up in order to look over the pilot's shoulder for the fun of the thing, as the extra head resistance caused may lead to the aeroplane falling below its critical gliding speed, and so bring about an accident.

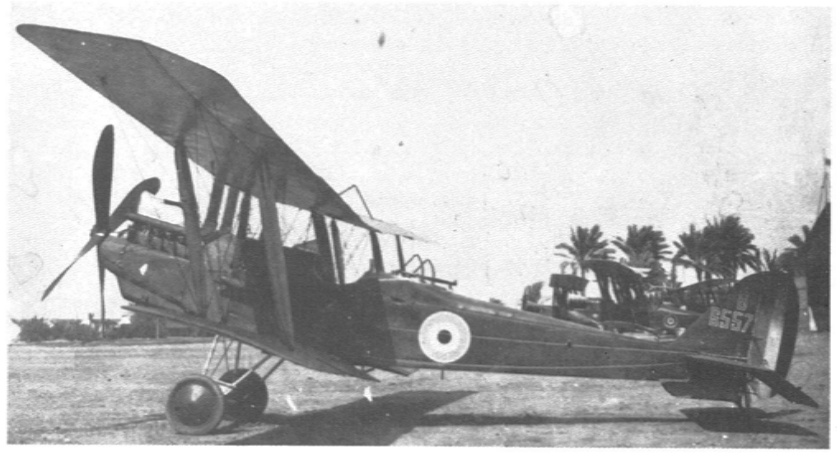
At the request of Lord Cowdray, Chairman of the Air Board, the Factory conducted a series of spinning trials in February 1917 to determine the cause of the difficulty. Three machines were tested; a standard production example, another with an enlarged fin, and a third in which the engine thrust line was less inclined. The report of these trials, dated 5 March, concluded that the standard R.E.8 could only be spun either by a determined effort or by serious misuse of the controls. The report also criticised standards of training, for many new pilots reached the Front after only a few hours' instruction, and with no knowledge of spin recovery.



R.E.8 A3433, built by the Siddeley Deasy Motor Car Company, with the initial form of fin and the small sump cowling.

As with the F.E.8 the previous summer, the publication of this report appeared sufficient to restore confidence in the machine. Its production and introduction into front-line service continued, a total of fifteen Corps Squadrons eventually being equipped with the type, as well as units in Palestine and Mesopotamia.

However, the Farnborough staff did not rest upon their laurels, but continued to investigate the R.E.8's spinning characteristics, experimenting with various forms of fin and rudder, some of which were balanced. They finally settled for a small increase in the area of both the dorsal and ventral



R.E:8 6557 of 142 Squadron with the slightly enlarged fin adopted for most production aircraft. Note the unfaired steel-tube undercarriage legs.

fins, the original rudder being retained. These changes were incorporated into production machines as soon as possible. If the report was correct in asserting that the R.E.8 could only be spun deliberately, it is tempting to speculate that the change was made only to appease popular opinion. A similar lack of explanation surrounds the fin of greatly increased area fitted to some machines in use at training establishments. If such a modification was considered advantageous for training, why was it not thought necessary for active service?

Regardless of these uncertainties, RFC crews generally thought well of the R.E.8. One man who flew it, Phillip Townsend, said, 'It was a fine

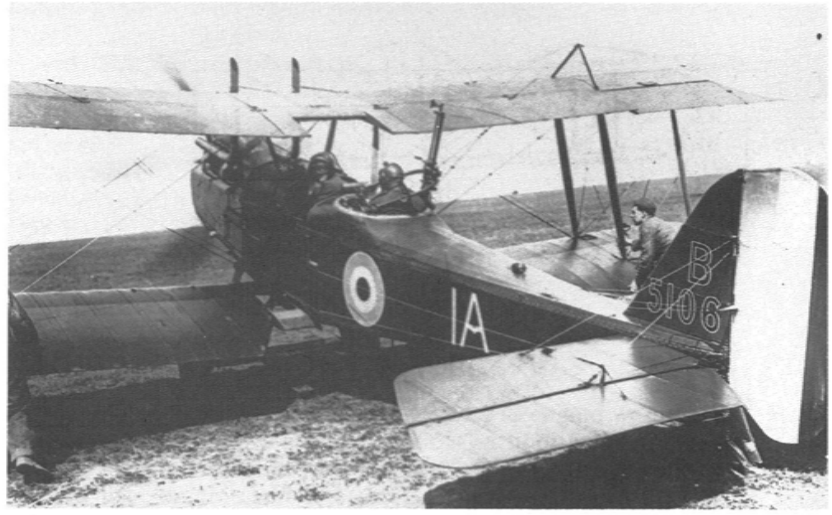
A tyro pilot leans proudly against R.E.8 A4737 at Scampton in 1918. This machine has the later sump cowling and the enlarged fin common at training establishments but never used in active service.
(Lincolnshire Aviation Museum)

This view of Daimler-built R.E.8 A4224 following a landing accident shows the roominess of the pilot's cockpit.
(PHT Green)

aircraft; easy, comfortable, lovely to fly. It would do anything asked of it up to its limited ability. It was very good on side slips, I never had any difficulty, the engine never let me down.'

A number were equipped, in service, with underwing bomb racks, and could carry either two 112lb bombs or up to eight 20lb bombs.

The R.E.8, like its predecessor, the B.E.2, served in every theatre of war. This example is over the desert somewhere in the Middle East.
(Lincolnshire Aviation Museum)



Daimler-built R.E.8 B5106 prepares to take off, with two mechanics assisting in manoeuvring. Note the cut-out in the lower wing roots to give the pilot a better view of the ground below.
(Military Aircraft Photographs)

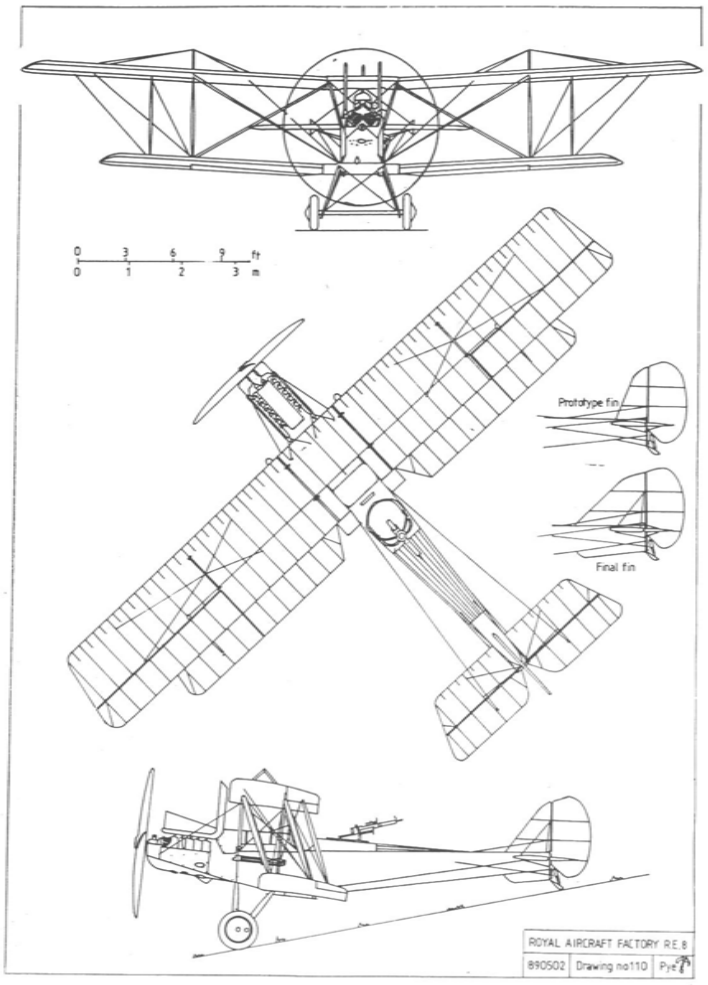
Affectionately known as the 'Harry Tate', after the contemporary music hall performer of that name, the R.E.8 remained in service and in production up to the end of the war, a total of 4,077 being built. Apart from modifications to the fin, very few detail changes were made to its design during its career, but those which were made included the substitution of all-wooden undercarriage legs for the faired-steel-tube units originally fitted, a deeper sump cowling and, in July 1917, a change of carburettor which marginally improved engine performance.

One batch of seventy-five was ordered with the Rolls-Royce Eagle engine, but the Eagle was never available in sufficient quantities to meet the need of those aeroplanes which were unable to accept any other power unit, so no R.E.8 was ever thus powered.

One example was retained by the Factory, and was used to test an experimental R.A.F.4d engine which had its output boosted to 200hp by supercharging via an exhaust-driven Rateau turbine. Initial overheating problems were solved by fitting a hugely enlarged air scoop over the cylinder heads. Testing was cut short when the turbine burst on 4 May 1918 and the experiments were discontinued. A four-bladed variable-pitch propeller was also tested with this engine, but was removed after two flights because its adjustment mechanism was unsatisfactory.

A small number of R.E.8s was supplied to Belgium, and these were converted upon arrival to the water-cooled Hispano-Suiza V-8 engine, enclosed within a neat, extensively louvred cowling.

Like many of its contemporaries which were designed for a specific rôle in



war, the R.E.8 found virtually no use after the Armistice, either with the RAF or on the civil register.

Powerplant:	140hp R.A.F.4a V-12
Dimensions:	
span	42ft 7in (upper); 32ft 7½in (lower);
chord	5ft 6in;
stagger	2ft 0in;
wing area	377½ sq ft;
gap	6ft 3½in;
dihedral	3½°;

length	27ft 10½in;
height	11ft 4½in.
Weights	1,803lb (empty); 2,869lb (loaded plus 2 × 112lb bombs).
Performance	
max speed	103mph at sea level;
stalling speed	47mph
ceiling	13,500ft;
climb	21min to 6,500ft (with 2 × 112lb bombs);
endurance	4¼hrs.

R.E.8a

In December 1916 a 200hp Hispano-Suiza V-8 engine was experimentally installed in R.E.8 A95, one of the original Farnborough-built batch. In this form the machine was referred to as the R.E.8a. It had a neat radiator and engine cowling reminiscent of that of the S.E.5.

Although no performance figures survive for this variant, the almost fifty per cent increase in power can only have brought about a significant improvement. However, production difficulties with the Hispano-Suiza were already delaying the completion of S.E.5as, for which there was no effective alternative powerplant, and there were never any engines to spare to enable the R.E.8a to be put into production.

Dimensions
As R.E.8
Weights and performance unknown

R.E.9

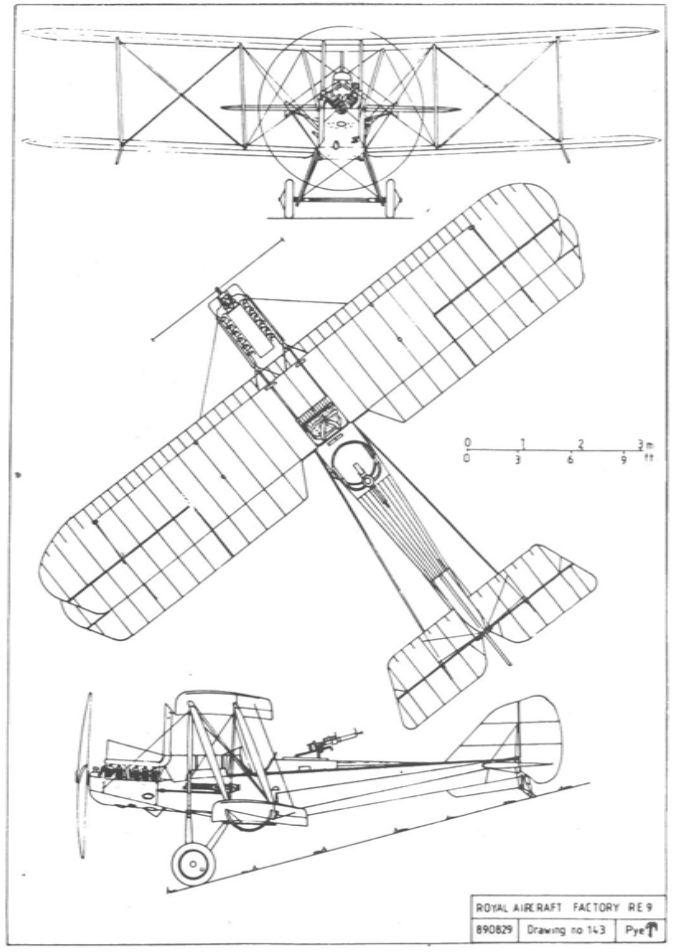
In mid-1917 a production R.E.8, A4600, had its wings replaced by those from a B.E.2d. Flight trials proved satisfactory and, since this wing structure was stronger than the standard R.E.8 assembly, drawings were prepared for a production version, to be designated the R.E.9.

It may have been the intention of H P Folland, the machine's designer, to settle all the criticism levelled at the R.E.8, for, in addition to its new equal-span, two-bay wings with blunt tips and narrow-chord ailerons hinged from a false rear spar, the new machine was to have an enlarged fin and an aerodynamically balanced rudder. A second machine, A3561, was similarly modified, but had ailerons of slightly shorter span. However, test results showed no advantage in performance over that of the standard R.E.8, the rate of climb being somewhat poorer, and the new design was consequently not adopted for production.

The eventual fate of the two machines is not known, although A3561 was retained at Farnborough as a test bed for some time, and was fitted with

various modified control surfaces and also, during 1918, with a 265hp Sunbeam Maori engine.

A broadly similar design, designated the R.T.1, was produced by the Siddeley Deasy Motor Car Company, where both F M Green and J Lloyd had taken up employment after leaving Farnborough. It appears to have been based upon preliminary work previously undertaken at the Royal Aircraft Factory concurrently with the R.E.9 project. The R.T.1 had a modified R.E.8 fuselage, for which type the company was a contractor, to which were fitted two-bay wings of new design, the upper wing being of greater chord than the lower. Three prototypes were built and tested, but the type was not adopted by the RFC.

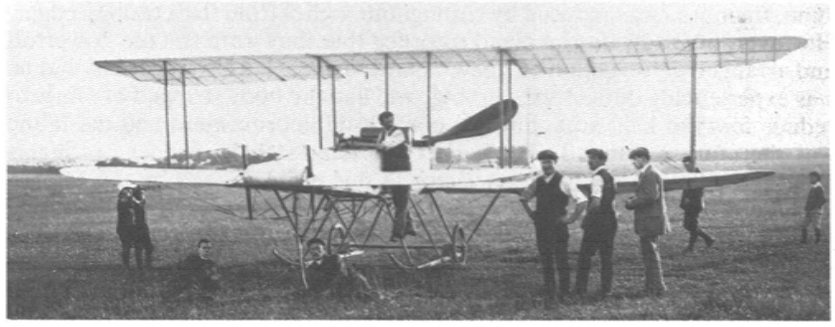


Powerplant:	140hp R.A.F.4a V-12
Dimensions:	
span	38ft 6in;
chord	6ft 0in;
wing area	382 sq ft;
gap	6ft 3½in;
length	27ft 7in;
height	10ft 5in.
Weight:	2,803lb (loaded).
Performance	
ceiling	13,000ft.

S.E.1

The first aeroplane built at Farnborough after the hiatus which followed the dismissal of Cody and Dunne came about as a result of a subterfuge, for the War Office denied the Factory the right to design and build aeroplanes. In the late summer of 1910 a Blériot XII of uncertain history was being operated on Salisbury Plain by a group of Army officers led by Lt Cammell (to whom ownership of the machine has sometimes been attributed), and towards the end of the year suffered considerable damage in a crash, eventually finding its way to Farnborough for repair. One of Blériot's less-successful designs, the machine was reputed to be very tricky to fly, and although officially known as B1 it was popularly known as the *Man-Killer*. Mervyn O'Gorman therefore sought War Office permission to redesign the Blériot and to include controls of the Farman type, so that it might be flown by anyone familiar with the Farman. Such permission was granted, and the Farnborough design team, led by de Havilland and F M Green, set to work on the 'S' class machine which previous study had led O'Gorman to believe would prove most successful.

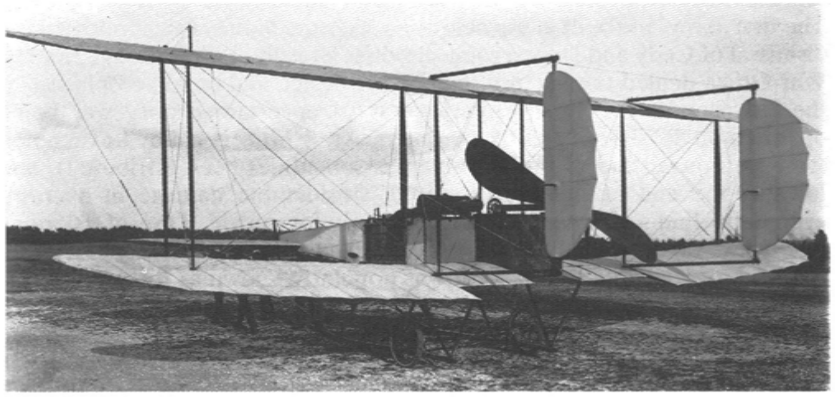
The result of their endeavours, the S.E.1, bore little resemblance to the tractor monoplane from which it was allegedly 'reconstructed', being a



The S.E.1 in late June/early July 1911, after the addition of a long skid beneath the nose. It underwent extensive modification and development.

canard pusher biplane and, although the shape of its wings was at least reminiscent of those of the Blériot, the only actual link between the two machines was the 60hp ENV 'F' engine.

The new machine made its first outing at dawn on 7 June 1911, when de Havilland made some taxying trials and broke two wheel spokes in the process. Therefore the wheels were moved forward to improve the balance. At the same time the twin rudder outriggers were shortened by three feet, bringing the rudders closer to the fuselage, because they were found to be vibrating and causing the mainplanes to flex. At 5.30am the following morning de Havilland made the first flight, even though the undercarriage problem was not yet entirely resolved. The machine flew about a mile, but its propeller shaft was found to have twisted. Following another outing on the 10th, de Havilland decided to restore the wheels to their original positions and to fit a skid under the forward elevators.

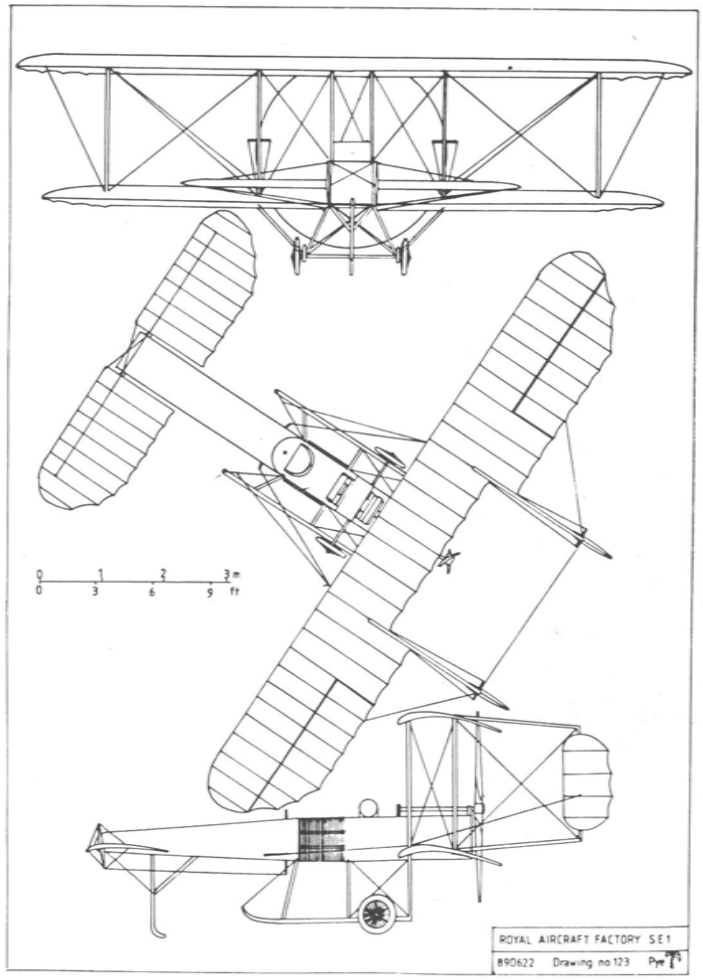


A three-quarter rear view of the S.E.1.
(*Royal Aerospace Establishment*)

The fore and aft stability was reported as good, but de Havilland thought the elevators to be too powerful. After the S.E.1's next flight, made on 28 June, their area was reduced by cutting four inches from their trailing edges. However, on 3 July de Havilland recorded that they were still too powerful, and arranged construction of a new canard surface. He also recorded that he was experiencing difficulty in turning, and had the body stripped of fabric to reduce forward keel area, but this made little improvement and the fabric was therefore reinstated. The earlier shortening of the rudder outriggers had clearly been a contributory factor to this problem, and by the 14th an additional rudder had been installed on the nose of the machine, operating in conjunction with those at the rear. At the same time the new elevators were fitted and the dihedral reduced. While turning was now improved, the S.E.1's designer/test pilot was still not satisfied, recording his opinion that the rear rudders appeared to be too sensitive. In addition, the radiators, which were on the fuselage sides, were found to boil over whenever the machine was at rest.

In the next two weeks the front skids were moved back, the wheels were again repositioned, and stronger rubber cords were fitted to the undercarriage. Several half-turns were made on 1 August, and on the 16th de Havilland successfully flew it to Laffan's Plain and back twice. The day's flying was brought to a premature end by a choked carburettor.

Two days later Lt Theodore Ridge, the Factory's Assistant Superintendent, took the S.E.1 up for the first time, despite de Havilland's advice that he should not do so because it was still a tricky machine. Ridge, who is reputed to have been something of a martinet, ignored him, sideslipped while attempting a sharp turn and crashed, receiving injuries from which he died later the same day. Thus the Factory's first design had resulted in tragedy, and the *Man-Killer* had finally lived up to its name.



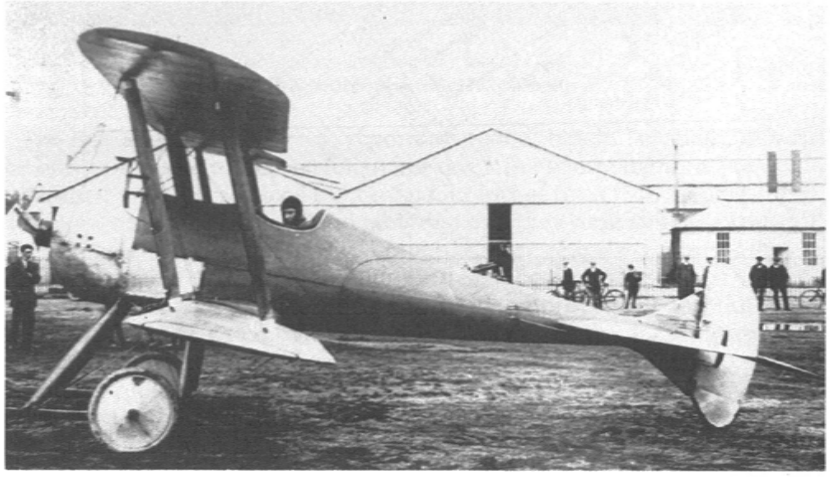
The type was presumably acknowledged to have been a failure, and the canard concept was not continued with, subsequent 'S.E.' types being of the 'scouting' rather than 'Santos' class.

Powerplant:	60hp ENV type 'F' water-cooled V-8
Dimensions:	
span	38ft 0in;
dihedral	2½°;
wing area	382 sq ft;
length	29ft 0in;
height	11ft 6in.
Weights:	1,200lb (empty); 1,640lb (loaded).

S.E.2

Following its crash in March 1913, the B.S.1 (which see) was rebuilt at a cost of around £900. Various minor improvements were incorporated, and at the same time it was redesignated S.E.2, S.E. standing for 'Scouting Experimental'.

The only apparent changes from its predecessor were a new tail unit and a revised engine cowling enclosing the 80hp single-row Gnome which replaced the 100hp two-row unit previously fitted. The new tail had symmetrical ventral and dorsal fins, inversely tapered elevators hinged from a semi-circular tailplane, and a high-aspect-ratio rudder, considerably larger



The S.E.2 on the edge of Farnborough Common, with Geoffrey de Havilland in the cockpit.
(PHT Green)

than the previous one, which had its bottom edge steel-shod to serve as a tailskid. The undercarriage and wing structure were unchanged, as was the divided tank holding both petrol and oil.

The rebuild was completed by October, several months later than O'Gorman had hoped. Again Geoffrey de Havilland acted as test pilot, although at least one RFC officer had flown the machine by 5 November, when O'Gorman reported on its performance to the Assistant Director of Military Aeronautics at the War Office. His report stated that the lower power of the smaller engine was compensated for by its reduced weight, and that the S.E.2's climb and maximum speed were nearly as good as those of the B.S.1. Its stalling speed was lower. O'Gorman also commented that the monocoque fuselage had proved expensive and slow to build, and suggested that he could make a conventional wire-braced structure at least as strong for the same weight.

A request to be allowed to retain the machine for continued trials was refused, and on 23 December the Factory was instructed to hand it over to the RFC. On 1 January 1914 O'Gorman replied, explaining that the machine was awaiting the replacement of a broken skid, and emphasising that the S.E.2 was an experimental design and not suited for service use. He also drew attention to a number of defects, which included cracked engine cowls, and suggested that it should remain in the Farnborough vicinity so that it could be attended to whenever necessary.

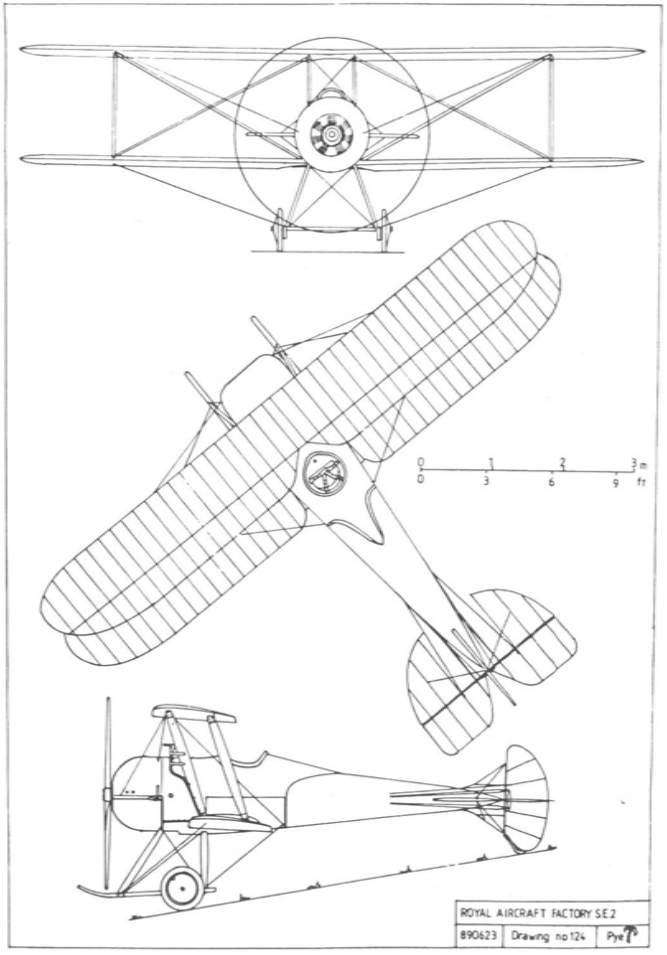
Despite his protests the S.E.2 was handed to 5 Squadron on 17 January, and was allotted the serial 609. Service pilots found it easy to fly and not difficult to land, although its shallow gliding angle made it hard to get into any field surrounded by trees unless it was very large. The view of the ground from the cockpit was described as good, but the forward view was considered impossible when the nose was raised in taxying or climbing.

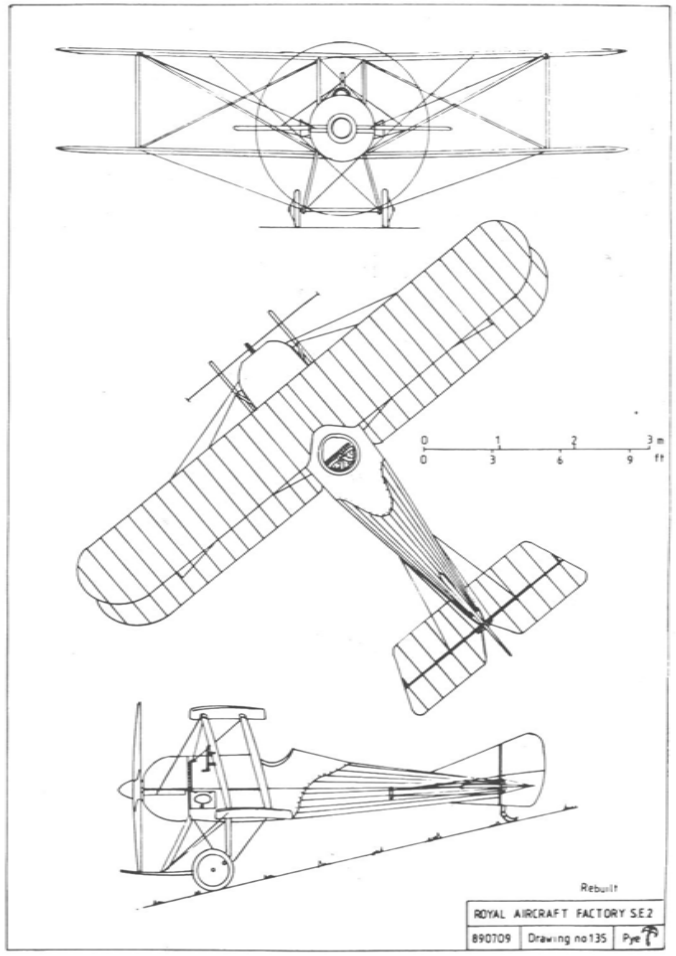
Early in April the S.E.2 was returned to the Factory for modification and repair. The monocoque fuselage was replaced by a conventional structure of four longerons, wire-braced and faired to circular section by formers and stringers, as previously suggested by O'Gorman. The engine cowling was

The rebuilt S.E.2, again seen on Farnborough Common, on 20 October 1914.
(Royal Aerospace Establishment)

again modified, and a new tail, similar to that designed for the S.E.4, was fitted. The wing structure was unchanged, but the bracing wires were replaced by Farnborough's new streamlined 'Raf wires'. Although the designation S.E.2a has often been applied to this version, no official or contemporary use of this suffix can be traced, the surviving Factory drawings referring to this version as the 'S.E.2 rebuilt'.

The modifications were completed by 3 October and, owing to the needs of war, after very brief tests at the hands of Frank Goodden the aircraft was returned to the RFC, joining 3 Squadron in France on 27 October. Never armed with more than service rifles, the S.E.2 remained a high-speed reconnaissance aeroplane, a true 'Scout'. Its eventual fate is unknown.



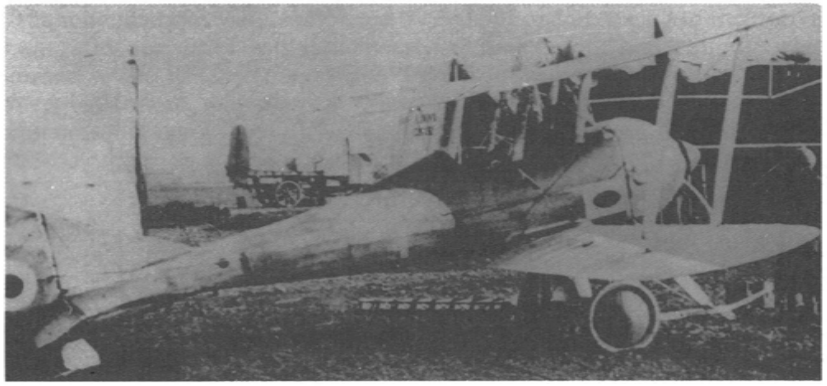


S.E.2

Powerplant:	80hp Gnome rotary
Dimensions:	
span	27ft 6in;
chord	3ft 9½in;
gap	4ft 7in;
wing area	188 sq ft;
length	20ft 5in;
height	9ft 3½in.
Weights:	720lb (empty); 1,132lb (loaded)
Performance:	
max speed	85mph at sea level.

S.E.2 rebuilt

Powerplant:	80hp Gnome rotary
Dimensions:	
length	20ft 10in.
Weight:	1,200lb (loaded).



The rebuilt S.E.2 in service with the Royal Flying Corps.
(JM Bruce/GS Leslie)

S.E.3

Conceived by Mervyn O'Gorman as a continuation of the B.S.1/S.E.2 formula, but powered by a nine-cylinder Gnome rotary of 100hp, the S.E.3 was shelved, after some preliminary design work by H P Folland, in favour of the more advanced S.E.4.

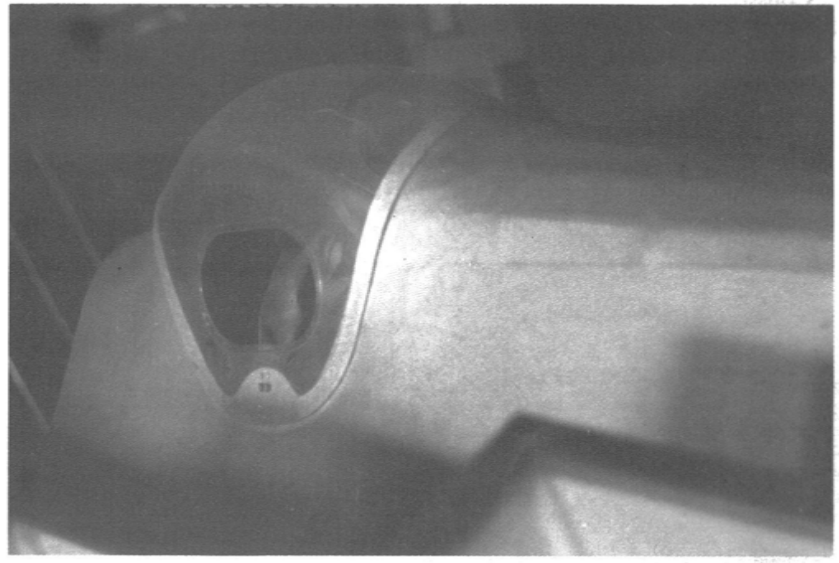
It was to have been an unstaggered biplane with single interplane 'I' struts. Its ailerons could also act together as landing flaps, or could be reflexed to reduce resistance in high-speed flight.

S.E.4

Yet another product of the fertile mind of Henry Folland, the S.E.4 was designed to be very fast, and may well have been the fastest aeroplane of its day. It was powered by a fully cowled fourteen-cylinder two-row Gnome rotary of 160hp, and the hub of its four-blade propeller was covered by a large, dish-like spinner. A fairly conventional fuselage structure based on four cross-braced longerons was faired to a circular cross-section by formers and stringers. The attention to streamlining included a moulded celluloid cockpit cover but, although this was made, it was never used because no pilot could be persuaded to fly the aircraft with it fitted.

The biplane wings were separated by single 'I' struts, their extremities extended to allow attachment to both the front and rear spars. The centre-section struts were of similar configuration, but were hollow, providing a route for the aileron cables. Full-span ailerons were fitted to all four wings, and incorporated a system, originally designed for the S.E.3,

The S.E.4, showing its neat engine cowling and the propeller spinner with its internal cooling fan.
(Military Aircraft Photographs)



A replica of the S.E.4's original cockpit canopy, which was never actually used in flight.

whereby they could be lowered together to act as landing flaps or reflexed to reduce drag for high-speed flight. The tailplane, like that of the S.E.2, incorporated the dorsal and ventral fin surfaces favoured by its designer. To reduce drag, the gaps between fixed and moveable surfaces were faired over

The S.E.4 with its original tripod undercarriage outside the Factory compound.
(Military Aircraft Photographs)

with elastic netting. The undercarriage comprised a transverse leaf spring carrying the wheels at its ends and attached to an inverted tripod of streamlined struts.

Construction was completed by 17 June, and test flying was begun by Norman Spratt. The sprung undercarriage was found to cause excessive rolling while taxying, landing or taking off, and by 23 July, when Spratt made taxying trials, it had been replaced by a conventional structure comprising an axle bound by rubber bungee within the apexes of two vee struts. He flew it again four days later.

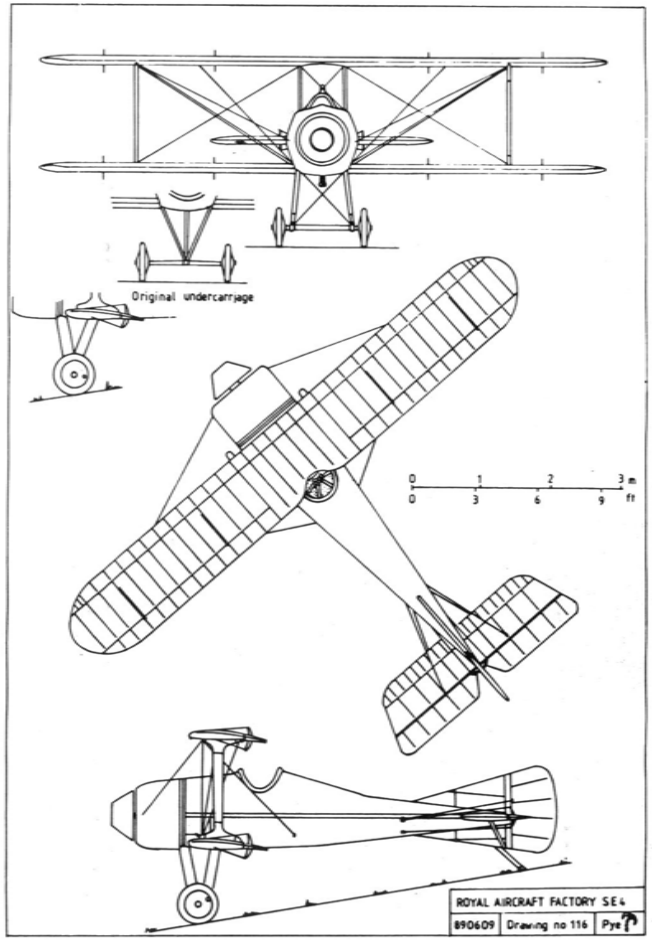
The 160hp engine proved troublesome, not only because of inadequate cooling, which was overcome by modifying the spinner, but because of its continued unreliability. It was eventually replaced by a single-row Gnome

The S.E.4 with its later vee undercarriage.
(Imperial War Museaum)

monosoupape rated at 100hp. This dramatically reduced the machine's previously impressive performance, the maximum speed dropping from 135mph to 92mph.

On 4 August the S.E.4 was flown by Maj J M Salmond, who found its performance and handling favourable, although its 52mph landing speed was considered too high for squadron pilots. Nevertheless it was taken over by the RFC, given the serial 628, and had a primitive camouflage scheme applied. It never saw active service because it was wrecked at 11.45am on 12 August when a wheel appeared to collapse on landing, its pilot fortunately escaping without injury. The aircraft was not rebuilt.

Powerplant: 160hp two-row Gnome rotary
100hp Gnome Monosoupape rotary

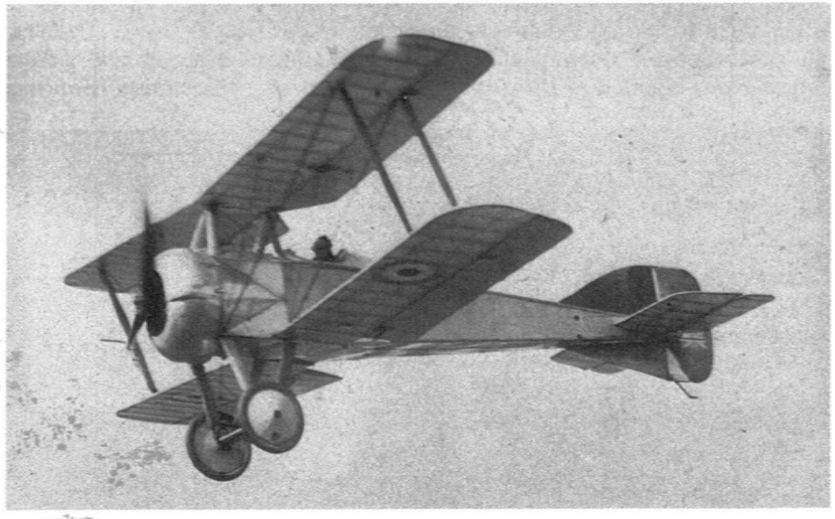


Dimensions:	
span	27ft 6in;
chord	3ft 9½in;
gap	5ft 1in;
wing area	188 sq ft;
length	21ft 4in;
height	9ft 0in (tripod undercarriage); 9ft 10in (vee undercarriage).
Performance:	
max speed	135mph (160hp); 92mph (100hp);
stalling speed	52mph;
initial climb	1,600ft/min (160hp);
endurance	1hr.

S.E.4a

This trim little scout owed little to the S.E.4, and the choice of designation is therefore hard to explain. Designed by Henry Folland late in 1914, it was intended to further the Factory's research into the relationship between stability and manoeuvrability, its wings incorporating 3½° of dihedral and having multi-function, full-span ailerons as used on the S.E.4. The only other link with its supposed parent was its horizontal tail surfaces.

The S.E.4a's fuselage was a conventionally cross-braced four-longeron structure, although the forward portion of each longeron was of steel tube,



S.E.4a 5611 in flight, showing the flat-sided fuselage which distinguished it from the slightly more streamlined prototype.
(PF Wright)

being joined by fishplates to the spruce rear fuselage members just aft of the single cockpit. The tailskid was hinged from the bottom of the sternpost, and enclosed within a fairing which continued the line of the ventral fin. There was no centre section, the wing panels being joined above the fuselage centreline and the centre section cabane struts forming inverted vees.

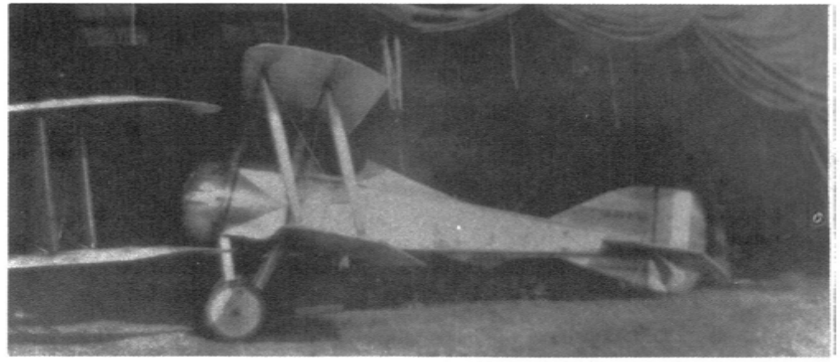
The powerplant was an 80hp Gnome rotary enclosed within a streamlined cowling which blended neatly into the fuselage, which was faired to a circular cross-section by formers and stringers. A large dish-shaped spinner covered the propeller boss.

The first prototype was completed on 23 June 1915, and flew for the first time two days later, with Frank Goodden at the controls. Tests using the ailerons as flaps showed that they could reduce the landing speed by 5mph, but it is debatable whether this relatively minor reduction justified the complexity of the system required to achieve it.

Three further examples were completed in the Farnborough workshops during the following six weeks, but they lacked the streamlining of the first machine. Their fuselages were flat-sided apart from a small fairing behind the cowling, and no spinners were fitted. They were handed over to the RFC as scouts, and were among the first British machines equipped with forward-firing machine guns. These were Lewis guns, mounted above the upper wing to fire clear of the propeller disc.

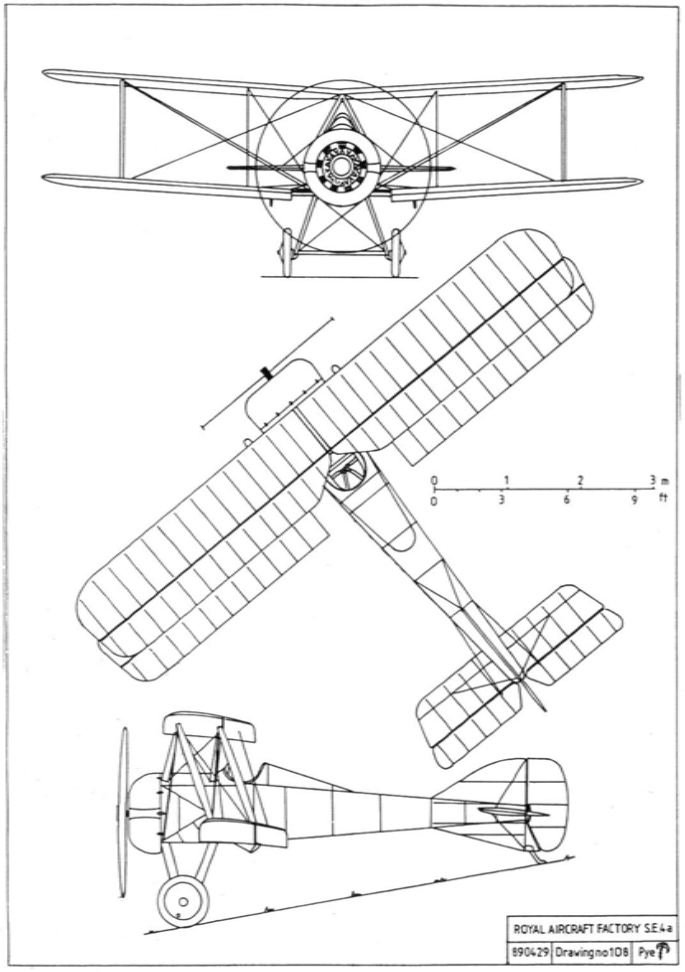
One S.E.4a crashed at Hounslow in September 1915, killing its pilot, Capt Binden Blood. The fates of the other aircraft are not known, although one, 5611, returned to Farnborough in June 1916 to have the 80hp le Rhône with which it had been built changed for a Gnome, as fitted to the others. In October this engine was replaced by a Clerget, but the reason for the change is not recorded.

Despite the S.E.4a's reputation as a good aerobatic aircraft, the rôle of single-seat fighter, to which it seemed perfectly suited, scarcely existed at the time of its emergence. Newer designs were already under way by the



A poor but unique photograph of S.E.4a 5610.

time the need for such a machine had arisen, and the S.E.4a did not go into production.



Powerplant:	80hp Gnome rotary
Dimensions:	
span	27ft 6in;
chord	4ft 2in;
gap	4ft 9in;
length	20ft 10½in;
height	9ft 5in.

S.E.5

Although it has occasionally been suggested that the design of this neat and attractive single-seater scout was carried out, at least in part, by Frank Goodden, it is doubtful whether his rôle extended beyond suggesting features he felt would be desirable, for H P Folland's style is clearly evident in every detail.

The S.E.5 was designed around the Hispano-Suiza V-8 engine, which, when it was first unveiled in mid-1915, was universally heralded as a significant advance in engine design. The use of this largely untried 200hp engine, with its reduction-geared propeller, was clearly intended from the start, because the sole armament originally envisaged for the S.E.5 was a Lewis gun mounted between the cylinder heads and firing through a hollow propeller shaft, an arrangement which obviated the need for synchronisation gear, which the Allies had yet to perfect.

The original drawings show a compact and very conventional tractor biplane, its pilot seated unusually high to give him the best possible view past the upper wing. The vertical tail included both dorsal and ventral fin surfaces and a rudder which, save for its rounded corners, was a narrow parallelogram. The control wires to the rudder and elevators were routed wholly within the fuselage to reduce drag. To make the aircraft safe to be flown by inexperienced or inadequately trained pilots, the wings were given a generous dihedral angle to afford a reasonable degree of stability, equally generous control surfaces being provided to allow good manoeuvrability. The tailplane incidence could be adjusted, via a control wheel in the cockpit, to trim the machine to fly 'hands off'.

One departure from convention, made in the interests of simplified construction, was the omission of compression ribs in the wing structure. Instead, some of the normal aerofoil ribs were formed from solid ply to carry the compression forces.

Unarmed S.E.5 A8917 fitted with an internal gravity tank and the early 'greenhouse' windscreen.
(Military Aircraft Photographs)

Three prototype S.E.5s were built, the first, A4561, being completed by November 1916. It differed from the original drawings in having the fin and rudder originally designed for the F.E.10, an unbuilt project also designed around the Hispano engine. As no 200hp engine was available, a direct-drive unit of 150hp was installed in A4561, which was not fitted with any armament.

Albert Ball shows the high seating position of the early S.E.5s in A8907, which also has the 'greenhouse' windscreen and over-wing gravity tank.

Frank Goodden took it up for its initial flight at about 10.00am on 22 November and, on landing after about ten minutes, exuberantly announced to the waiting spectators, 'She's a pixie!'. Capt Albert Ball, who was allowed to make a short flight the following day while on a visit to Farnborough, was less enthusiastic, comparing the new machine unfavourably with the lightness of the rotary-powered Nieuport which was then his usual mount. However, he was later to revise his opinion.

The second prototype, A4562, which appears to have been identical to the first, was test flown, again by Goodden, on 4 December. A heavy landing during subsequent testing necessitated a replacement undercarriage, and while it was in the workshop the machine was fitted with what would become the type's service armament. A belt-fed Vickers gun was mounted in the forward fuselage decking, offset to port and inclined at five degrees above the line of flight to lessen the effects of bullet drop and extend the effective range. The gun was synchronised to fire through the propeller disc by the recently developed Constantinesco gear. Since this gear could operate only a single gun at that time, a drum-fed Lewis gun was also fitted, on an overwing Foster mounting, firing above the propeller disc. Both an Aldis optical sight and a simple ring and bead were provided, the former directly in the pilot's line of sight and the latter fixed above the barrel of the Vickers gun.

The third prototype, A4563, had the 200hp geared engine for which the

type had originally been designed, but otherwise differed little from the two previous examples. It made its first flight on 12 January, with Goodden in the cockpit, and, after suitable modification, eventually became the prototype S.E.5a.

On 28 January 1917 the port wing cellule of A4562 folded up in flight and its pilot, Frank Goodden, was killed in the resulting crash. A committee of investigation headed by Dr A P Thurston concluded that the wings had failed owing to the inadequate strength of the compression ribs, allied with unsatisfactory attachment of the interplane struts to the spars, which had allowed the former to become detached. The Factory staff quickly redesigned these components and the modifications were incorporated in all production machines, the first batch of which was already well advanced in the newly extended Farnborough workshops.

The first production S.E.5 with its Aldis optical gunsight fitted through its 'greenhouse' windscreen.
(JM Bruce/GS Leslie)

The first production S.E.5, A4845, was tested at Martlesham Heath in March 1917. It was criticised both for its poor lateral control at low speeds, and for its huge 'greenhouse' windscreen which, although it was designed to protect the pilot in his rather elevated position, tended to distort his view. Research carried out at the Factory established that the cause of the former deficiency was the sharp outward rake of the wingtips, and plans were made to modify this, thereby reducing the overall wingspan by about fifteen inches.

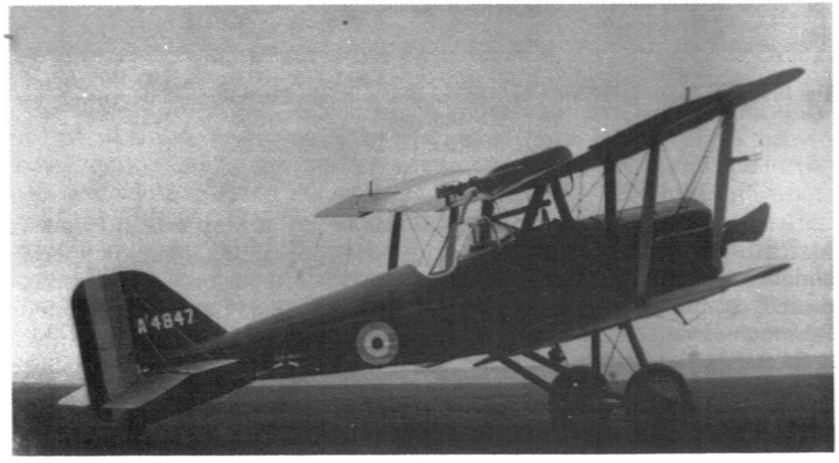
The first unit to be equipped with the S.E.5 was the newly formed 56 Squadron, whose pilots included Albert Ball. Before the CO, Maj Blomfield, would allow the pilots to begin operations, the greenhouse

S.E.5 A4853 displays its 'Avro' pattern windscreen and the unusually long taper to its head fairing.

windscreens were removed by squadron personnel and replaced by small flat screens intended for Avros. This modification was eventually made to all S.E.5s, and in addition the pilot's seat was lowered and a faired headrest was fitted.

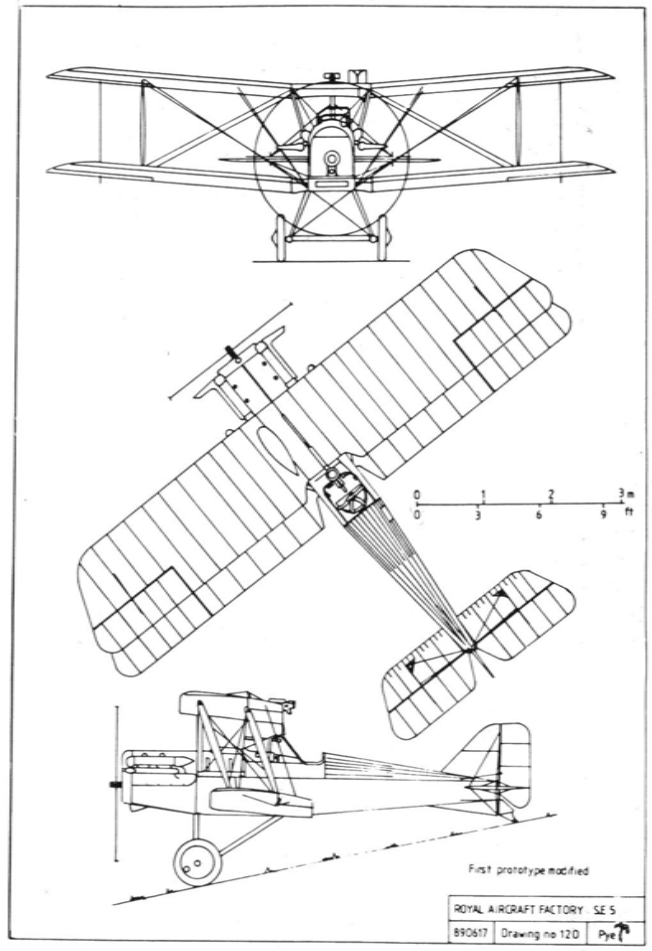
Later aircraft were fitted with long, straight exhaust pipes discharging aft of the cockpit, in place of the original 'T' shaped manifolds and stub exhausts. Radiator shutters, operated by the pilot, were added to assist in controlling engine temperature.

Only fifty or so machines had been completed when the decision was taken to fit all future machines with the 200hp engine, which was finally



An early S.E.5 with the 'greenhouse' windscreen and overwing gravity tank.

expected to become available in quantity. The shorter-span wings were also to be adopted at the same time, machines thus equipped being designated S.E.5a.



Powerplant:	150hp Hispano-Suiza V-8
Dimensions:	
span	27ft 11in;
chord	5ft 0in;
gap	4ft 7in;
wing area	249 sq ft;
dihedral	5°;
length	20ft 11in;
height	9ft 5in.

Weights:	1,390lb (empty); 1,935lb (loaded)
Performance:	
max speed	122mph at sea level;
ceiling	19,000ft;
endurance	2½hrs.

S.E.5a

The third prototype S.E.5, A4563, which had been fitted with a 200hp geared Hispano-Suiza at the time of its first flight in January 1917, was subsequently modified in an effort to overcome the defects noted in the Martlesham Heath report on the type. It therefore had the shorter-span wings, an internal gravity petrol tank and water header tank within the centre-section, a lowered pilot's seat and a faired headrest. Although no criticism appears to have been made of the original two-bladed propeller, a four-bladed unit of slightly reduced diameter was substituted, in accordance with common Factory practice.

An unidentified S.E.5a with the four-bladed propeller usually fitted to machines powered by the 200hp geared Hispano-Suiza engine. The aeroplanes in the background are B.E.2es.
(via PHT Green)

On 29 May Roderic Hill flew the modified aircraft to Martlesham Heath, where it received lightly favourable and enthusiastic reports. All production orders placed were therefore for the new type, now given the designation S.E.5a.

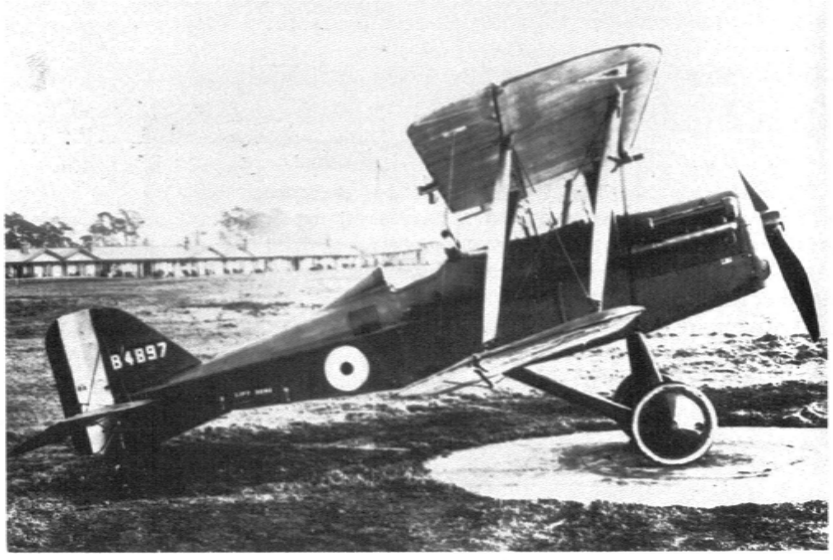
The aircraft industry was already swamped with work, and although Martin and Handasyde and the Air Navigation Company accepted orders, the majority went to companies previously engaged in other fields of engineering, including Wolseley Motors and Austin. Production was also undertaken by the Royal Aircraft Factory, and by the end of 1917 almost a thousand airframes had been produced.

An unidentified S.E.5a with the early form of undercarriage. Note the higher thrust line of the geared engine, which necessitated a modified Foster mounting to prevent the bullets from its over-wing Lewis gun striking the propeller.
(via RB Pope)

Unfortunately, owing to problems with the geared engine, and consequent delays in manufacture, more than 400 machines were stockpiled awaiting engines. In an effort to forestall this eventuality an order had been placed with Wolseley for a number of direct-drive engines. However, because of a misunderstanding, instead of producing licence-built examples of the well-proven 150hp version which powered the S.E.5, the company set about developing an uprated version, intended to give the same output as the unreliable geared variant. By increasing the compression ratio from 4.5:1 to 5.6:1 it became possible to obtain 220hp at 2,000rpm, although this speed was rather high by the standards of the day. An example of this new engine, named the Viper, was tested in a production S.E.5a, after which its compression ratio was slightly reduced to 5.3:1. Although this lowered the nominal power output to 200hp, it gave a slightly enhanced performance at altitude and was adopted for production. A geared version, with the same rating but a lower propeller speed, was also produced, although in much smaller quantities.

To facilitate the installation of whichever of these engines was available, a new radiator, split into two separate banks each with its own shutters, was developed. This left a central vertical slot which could accommodate the different thrust lines of the various engines. The new radiator, which gave the machine a more purposeful, aggressive appearance, was fitted to all Wolseley-powered aircraft, stocks of the original one-piece radiator being used up on the Hispano-powered machines for which it had been designed. Hispano-powered S.E.5as also had small fairings over the ends of the projecting cylinder heads, while those with the Wolseley, which projected slightly less, did not. Machines with geared engines, of whatever make, were fitted with four-bladed propellers, and had a modified Foster mounting for their overwing Lewis guns to allow for the higher thrust line.

This machine is most probably A4864, and was originally built as an S.E.5. It has the low thrust line of the ungeared engine, but the long exhaust pipes and all-wood undercarriage of later examples. The curved headrest is unusual.
(via PHT Green)



Farnborough-built S.E.5a B4897, with the strengthened all-wood undercarriage introduced on later machines.
(via RB Pope)

While the engine shortage was at its most acute a small number of S.E.5as were fitted experimentally with the 200hp Sunbeam Arab, but this unit proved less reliable than the Hispano it was intended to replace, and was not adopted for mass production.

Complaints that the original steel-tube undercarriage lacked sufficient resilience for unprepared fields led to the development of a new type, with twin front legs in a narrow inverted vee, all encased in wooden fairings. Another, all-wood version was found to be equally successful and, being far simpler to produce, was adopted thereafter.

Overall, the S.E.5a was a great success, being strong, easy to fly, a stable gun platform, and possessing a performance at least equal to that of any adversary. Its success as a fighter, measured in terms of combat victories, was second only to that of its 'rival', the Sopwith Camel, but the Camel was a much trickier machine to fly and had an unenviable reputation for killing inexperienced pilots. Marshal of the Royal Air Force Lord Douglas of Kirtleside, who flew the type in 1917/18, said in his autobiography, 'Many of us felt that it was the best fighter in Britain in the First World War'. He described it as 'a very strong aeroplane', and 'the most beautiful aeroplane that has ever been built'.*

Despite the S.E.5a's acknowledged success, the Factory continued to explore ways of enhancing its performance. In one experiment the S.E.5 A4862, which had remained at Farnborough and been converted to S.E.5a configuration, had its nose covered by a blunt fairing, the car-type radiator being replaced by an underslung radiator beneath the fuselage. This appears to have been formed by mounting two Viper-type radiator blocks together, one above the other. As no significant improvement in performance

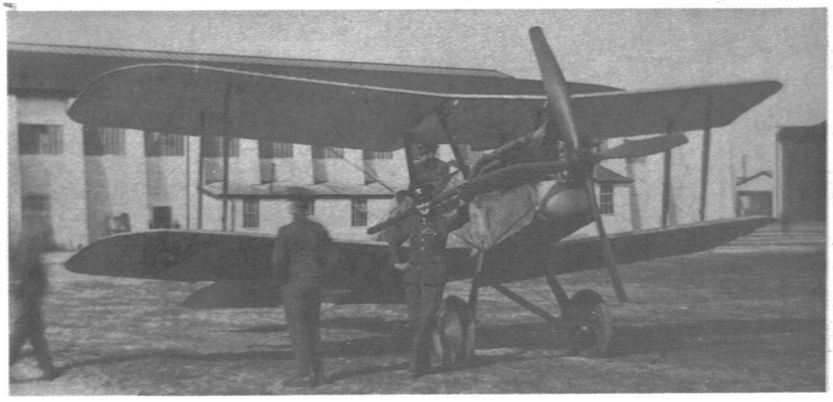
A modified S.E.5a with a blunt nose and an underslung radiator. It showed no definite improvement over the standard model.
(Imperial War Museum)

* *Years of Combat* (London, 1953).

An unidentified S.E.5a fitted with an experimental low-aspect-ratio fin and rudder of remarkably Teutonic appearance. The handle of the starting magneto is visible just below the exhaust pipe, where it could be operated either by the pilot or by a mechanic standing alongside.
(JM Bruce/GS Leslie)

resulted, the modification was not adopted, especially as the car-type installation was slightly easier to produce.

Various alternative tail surfaces were designed, including one with twin fins and rudders and another with a rounded vertical tail which gave the machine a vaguely Teutonic appearance. None of these was adopted, and, as no particular criticism appears to have been levelled at the aeroplane's



S.E.5a G-EBCA (ex-E5956) fitted with an 80hp air-cooled Renault engine in private ownership. Its maximum speed thus powered is believed to have been about 65mph.

existing tail surfaces or its control or stability, it can only be assumed that the installations were part of a programme of 'pure' research, in keeping with the Royal Aircraft Factory's redefined rôle. However, one tailplane modification which was adopted, although for relatively few machines, was the use of elevators of reduced chord. These were designed to increase manoeuvrability, but appear to have had little effect.

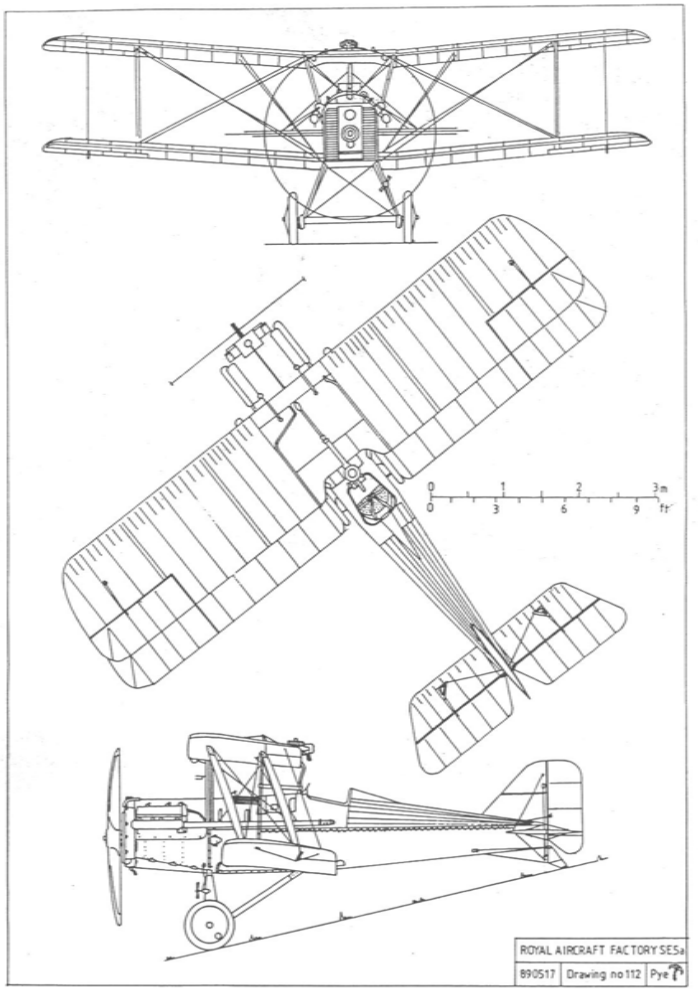
To facilitate pilot training a number of S.E.5as were converted to dual-control two-seaters. The main petrol tank was drastically reduced in size to make room for the second cockpit, which was positioned under the centre section, and no armament was carried.

Tests were carried out with a variable-pitch propeller, at least one machine being so equipped, but no real success was achieved during the existence of the Royal Aircraft Factory.

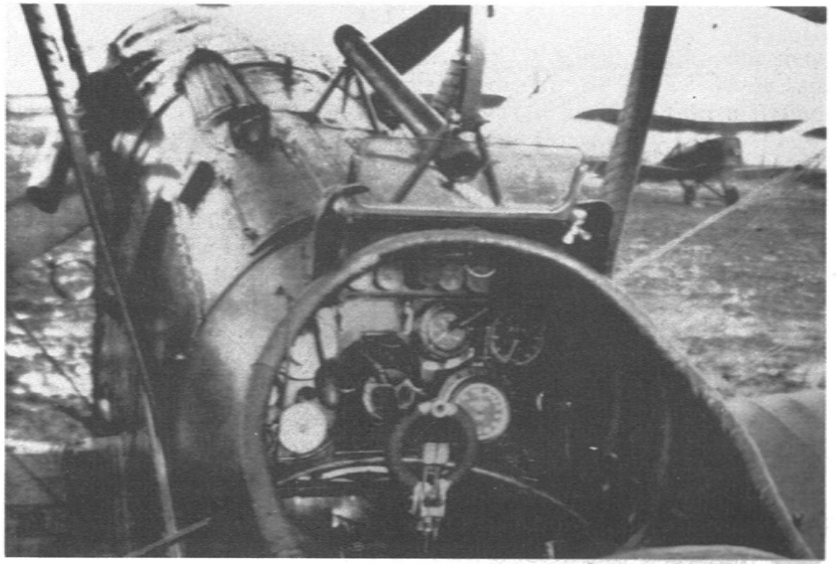
A postwar skywriting modification of S.E.5a G-EBGL (ex-F7960). Later skywriters had their exhausts extended beyond the tail, the rudder being divided to accommodate them.
(Military Aircraft Photographs)

By the time of the Armistice 5,205 S.E.5as had been completed, the total reaching 5,269 before production finally ceased. After the war the type continued to serve with the United States Air Service and South African Air Force. Those belonging to the Royal Air Force were quickly disposed of, and a number found their way on to the civil register, at least one being powered, in the interests of economy, by an 80hp air-cooled Renault, with which the top speed fell to about 65mph.

Apart from pleasure and sporting use, the S.E.5a pioneered the art of 'skywriting' both in England and in the USA, a use which served to ensure that three examples would be preserved for posterity in England. Two more survive in the museums of the Australian and South African air services, and two American Eberhart-assembled examples are also extant.



Powerplant:	200hp Hispano-Suiza V-8 200hp Wolseley Viper V-8 200hp Wolseley Adder V-8
Dimensions:	
span	26ft 7½in;
chord	5ft 0in;
gap	4ft 7in;
wing area	245 sq ft;
dihedral	5°;
length	20ft 11in;
height	9ft 5in.
Weights:	1,531lb (empty); 2,048lb (loaded).



An S.E.5a cockpit, showing the Aldis optical gunsight directly in front of the pilot, and the Vickers gun offset to port. The exhaust pipes have been shortened, leaving a redundant support bracket on the fuselage side below the Vickers gun.
(via RB Pope)

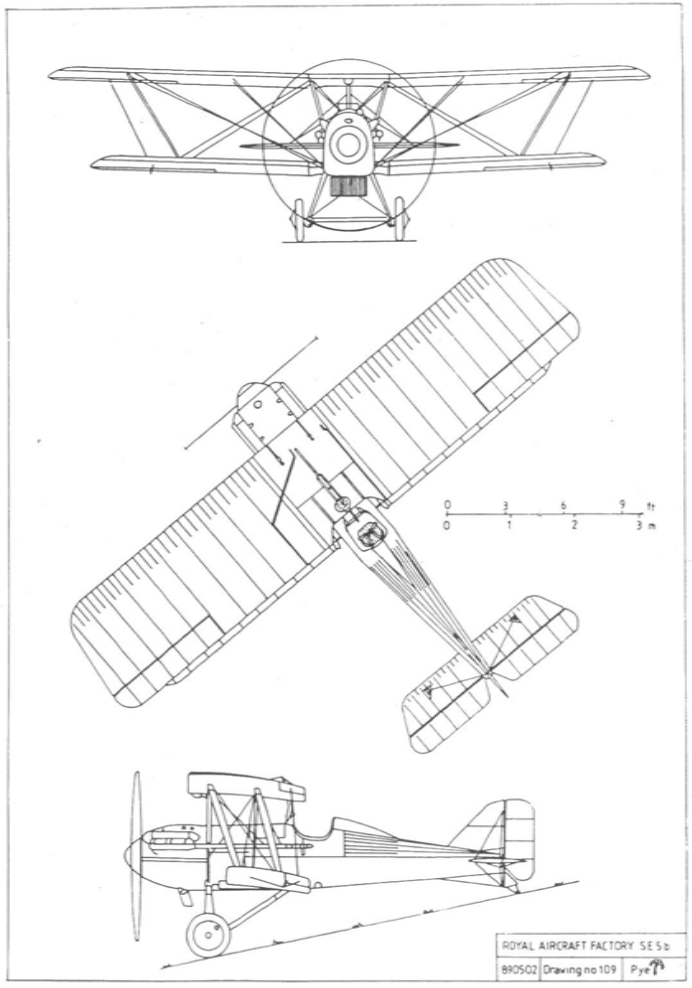
Performance:	
(Wolseley Viper)	
max speed	136mph at sea level; 117mph at 15,000 ft;
ceiling	23,000ft.

S.E.5b

Early in 1918 A8947, the last of a batch of Farnborough-built machines, which had been ordered as an S.E.5 but completed as an S.E.5a, was modified to become the S.E.5b. New wings of unequal span and chord were fitted, the upper-wing ailerons being of narrow chord and hinged from an auxiliary spar. The interplane struts were raked outwards. The nose was streamlined, a large shallow spinner covered the propeller boss, and a retractable underslung radiator was provided to cool the 200hp geared Hispano-type engine.

Testing revealed that the induced drag of the large upper wing offset any advantage gained by the streamlining of the nose, and the anticipated improvements in performance were not realised.

Some time after the Armistice it was fitted with standard S.E.5a wings of equal span and chord, and was tested against a production S.E.5a with a nose radiator. The production machine was found superior in powered



flight, the modified machine only bettering its performance when gliding with its radiator retracted.

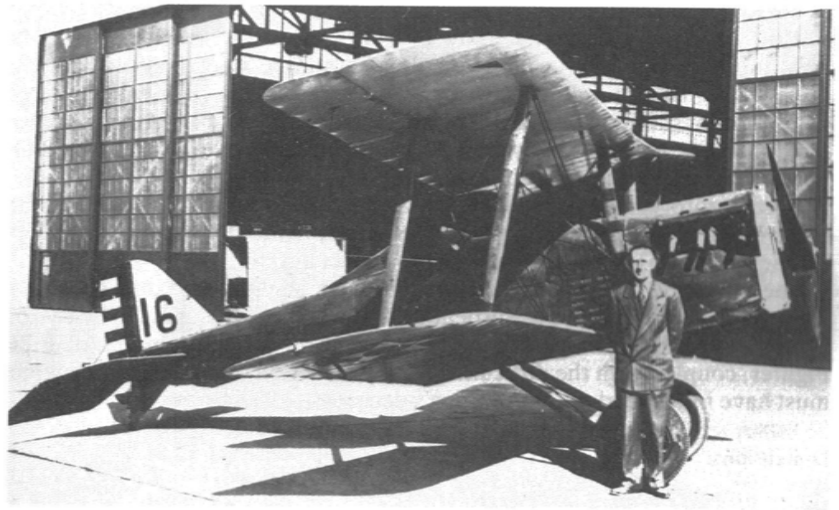
Powerplant:	200hp Wolseley Viper V-8
Dimensions:	
span	30ft 7in (upper); 26ft 6in (lower);
chord	6ft 0in (upper); 4ft 3in (lower);
wing area	278 sq ft;
length	20ft 10in;
height	9ft 6in.

S.E.5E

After the war the Eberhart Company in the USA assembled about sixty S.E.5as, largely from spare parts, for use by the US Air Service. These had plywood-covered fuselages and were powered by direct-drive 180hp Hispano-Suizas built under licence by the Wright Company.

The designation S.E.5E has frequently been applied to these machines.

Powerplant:	180hp Wright-built Hispano-Suiza V-8
Dimensions:	As S.E.5a.



Eberhart-assembled S.E.5a (or S.E.5E) 22–325, photographed in the USA in 1926. *(via RB Pope)*

S.E.6

This was to have been a single-seater scout for which both the Rolls-Royce Falcon and the supercharged R.A.F.4d have been suggested as possible powerplants. It was to have had equal-span wings separated by 'N' struts. It is doubtful whether anything other than preliminary sketches were made, and no drawing connected with it has survived.

S.E.7

The S.E.7 appears to have been a radial-powered variant of the S.E.6, with which it is known to have shared its wings and tail surfaces. The projected engine was the R.A.F.8, for which a long-chord cowling was developed by windtunnel tests upon scale models.

The design was not completed, but it may have formed the basis for the S.R.2, designed by the Siddeley Deasy Company, of which Fred Green was then chief engineer and where the R.A.F.8 engine was developed into the Jaguar.

T.E.1

The T.E. classification was originally an abbreviation of 'Tatin Experimental', and was therefore reserved for aeroplanes with propellers behind their tails, but no machines of that type were built. In the case of the T.E.1 there is no record of what the 'T' stood for, the aircraft being a two-seat 'fighter' based upon a scaled-up S.E.5.

The drawings, completed early in 1917, show the machine with the now-universal variable-incidence tailplane and a steerable tailskid. Its intended armament was to have been a forward-firing Vickers gun fitted with the Constantinesco synchronisation gear, and a Scarff-ring-mounted Lewis for the observer. Power was to be provided by a 200hp Hispano-Suiza, or a variant thereof.

Three prototypes were ordered on 23 February, to be completed within three months, and three more examples were planned for later completion. The serials A8951–8956 were allotted to the six aircraft.

The first T.E.1 was approaching completion, slightly later than specified, when, on 11 June, work was suspended and was never resumed. The reason has not been discovered, but the emergence of the superb Bristol F.2B Fighter, coupled with the difficulties with production of the Hispano engine, must have influenced the War Office's decision.

Dimensions:	
span	31ft 3in;
chord	5ft 8in;
wing area	327 sq ft;
length	25ft 0in;
height	9ft 6in.
Weight:	
(estimated)	2,300lb (loaded).
Performance:	
(estimated)	
max speed	120mph;
endurance	4hrs.

Appendix 1

Prototype production

The following table includes details of all prototype or one-off experimental aeroplanes built from scratch at the Royal Aircraft Factory between January 1911 and December 1918. It does not include machines mass-produced for service use, nor new types (such as the B.E.9) which were genuinely rebuilt from existing machines.

Type	*Engine*	*Order No*	*Order date*	*Completed*	*Serial No*
A.E.3	Sunbeam Arab	1038/2	16.1.18	29.3.18	B8791
Aerial Target	ABC Gnat	2781	8.2.17	5.6.17	B8957
B.E.1	60hp Wolseley	A45	1911	13.3.12	201
B.E.2	60hp Renault	A106	1911	30.3.12	601
B.E.3	50hp Gnome	560/4	1912	26.6.13	203
B.E.7	140hp Gnome	337	1912	28.2.13	438
B.E.8	80hp Gnome	560/7	1912	1.12.12	416
B.S.1	100hp Gnome	560/9	1912	25.3.13	–
C.E.1	R.A.F.3a	1018/1	1.9.17	25.12.17	N97
F.E.2	70hp Gnome	–	1911	1911	604
F.E.3	75hp Chenu	560/6	1912	3.3.13	605
F.E.4	R.A.F.4a	485	17.1.14	13.3.6	7993
F.E.6	120hp Austro-Daimler	481	18.8.13	24.11.14	–
F.E.8	100hp Mono Gnome	233	21.5.15	15.10.15	7456
F.E.9	200hp Hispano-Suiza	3134	3.10.16	4.4.17	A4818
N.E.1	200hp Hispano-Suiza	1022/1	19.5.17	5.9.17	B3971
R.E.1	70hp Renault	470	11.4.13	20.9.13	607
R.E.2	100hp Renault	316	1.11.12	26.10.13	17
R.E.3	120hp Beardmore	317	11.10.12	1913	–
R.E.5	120hp Beardmore	248	1913	26.1.14	613
R.E.8	140hp R.A.F. 4a	2090	4.3.16	6.6.16	7996
S.E.1	60hp E.N.V.	A9	1911	1911	–
S.E.2	80hp Gnome	472	11.4.13	13.10.13	609
S.E.4	160hp Gnome	487	3.12.13	17.6.14	628
S.E.4a	80hp Gnome	–	27.8.14	29.6.15	5611
S.E.5	150hp Hispano-Suiza	2746	21.7.16	20.11.16	A4561

Appendix 2

Production machines

The following list of machines built to Royal Aircraft Factory designs cannot be regarded as complete, because numerous 'new' machines were assembled from salvage and spare parts at various Aircraft Repair Depots. Such rebuilt machines have been included wherever an identity can be established.

B.E.2/2a

Royal Aircraft Factory:	46, 47, 267, 272.
Armstrong Whitworth:	383, 385.
British and Colonial:	217, 218, 220, 222, 225–242, 245, 248–250, 273, 449.
Coventry Ordnance Works:	318, 347–349, 384, 474.
Grahame-White:	299, 321.
Handley Page:	460, 461.
Vickers:	314, 316, 317, 320, 336, 372, 441, 442, 447, 452–4.
Unknown:	327–9, 331, 332, 368, 457, 465, 466, 486–471, 475, 477, 478, 601, 602, 612, 622, 635, 667, 668, 709.

B.E.2b

Royal Aircraft Factory:	A376 (from spares).
British and Colonial:	396.
Jonques:	2175, 2180, 2770–2819.
Whitehead Aviation:	2884–2889.
Unknown:	484, 487–8, 492–3, 646, 650, 666, 676, 687, 705, 722, 733, 746.

B.E.2c

Armstrong Whitworth:	1780–1800, 2000–2029.
Blackburn:	964–975, 1123–1146, 3999, 8606–8629, 9951–10000.
William Beardmore:	1099–1122, 8714–9475.
British and Colonial:	1652–1747, 4070–4219.
Daimler:	2030–2129, 2570–2669.
Eastbourne Aviation:	1183–1188.
Grahame-White:	1147–1170, 8293–8500.
Hewlett and Blondeau:	976–987, 1189–1194.
Martin and Handasyde:	988–999.
Ruston, Proctor:	2670–2769.
South Coast Aviation:	1424–1435.
Vickers:	1075–1098, 1748–1779, 4710–4725, 5413–5441, 7321–7345.
G & J Weir:	4300–4599.
Wolseley Motors:	2470–2569, 5384–5403.
Rebuilds:	B728, B792, B8794, B8816, B9444, B9459, B9993–F9627.
Unknown:	601, 602, 4016, 4019, 5616.

B.E.2d

British and Colonial:	5730–5879, 7058–7257.
Ruston, Proctor:	6228–6327.
Vulcan Motor:	6728–6827, A1792–1891.
Rebuilds:	B705, B707–8, B719, B3954, B8825, C9988–9, C9995, F4218, F9567, F9571, H8256.

B.E.2e

Barclay Curle:	A1261–1310, C7001–7100.
British and Colonial:	A2733–2982, A8626–8725, B4401–4600, C1701–1753 (order cancelled).
British Caudron:	B6151—6200.
William Denny:	A1361–1410, C6901–7000.
Napier and Miller:	A1311–1360, C7101–7200.
Robey:	N5770–5794 (order cancelled).
Vulcan Motor:	A1792–1891, B3651–3750.
Wolseley Motors:	A3049–3168.
Rebuilds:	B702, B706, B709, B710, B712, B719, B722–5, B728, B748, B770, B772, B790, B797, B4004, B4006, B4022–3, B4026, B8820, B8828, B8831, B8835, B8849, B8854, B8863, B9453–4, B9457, B9469, B9474, B9938, B9940–1, B9943, B9957, B9998.

B.E.8

Royal Aircraft Factory:	209.
British and Colonial:	636, 2181–2184.
Coventry Ordnance Works:	2131–2154.
Vickers:	624–5, 656, 2130.
Unknown:	365, 373, 377, 391, 399, 423–4, 632, 645, 658, 663, 670, 693, 725, 727, 729, 736, 740.

B.E.8a

Coventry Ordnance Works:	2155–2174.
Vickers:	2133–2154.

B.E.12

Daimler:	6478–6677.
Standard Motor:	6136–6185.
Rebuilds:	B701, B720–1, B749, B1500, B8826, B9462, B9950.

B.E.12a

Daimler:	A4006–4055, A6301–6350.
Coventry Ordnance Works:	A562–611.

B.E.12b

Daimler:	C3081–3280 (many completed as B.E.12).
Rebuilds:	B718, C9992.

F.E.2a

Royal Aircraft Factory:	2864, 4227–8, 4253, 4295, 5642–5648.

F.E.2b

Royal Aircraft Factory:	6328–6377, A5338–A5437 (cancelled), A8950.
Barclay Curle:	F3468–3547, J601–650 (cancelled).
Boulton and Paul:	5201–5250, 6928–7027, 7666–7715, A5438–5487.
Garrett and Sons:	D3776–3835, E6687–6736 (cancelled).
Ransomes, Sims & Jefferies:	B401–500, C9786–9835, D9900–9999, E7037–E7136, F3768–3917 (cancelled).
Alex Stephen and Sons:	D9081–9230, F4071–4170 (cancelled).
G & J Weir:	4256–4292, 4838–5000, A778–877, A5500–5799.
Rebuilds:	A8895, B704, B7779, B7782, B7788, B7794–5, B7800, B7808–9, B7813–16, B7836–7841, B7843, B7847–9, B7856, B7872, B9740–9789, F5858–9, F5862, F6071, F6080, F9550, F9566.
Unknown:	D9740–9799.

F.E.2d

Royal Aircraft Factory:	7995, A1–40, A1932–1966, A5143–5152.
Boulton and Paul:	A6351–6600, B1851–1900 (many completed as F.E.2b).

F.E.2h

Ransomes, Sims & Jefferies:	A6545 (modified F.E.2d)
Ransomes, Sims & Jefferies:	E3151–3153.
Garrett and Sons:	F9296–9395 (cancelled).

F.E.8

Royal Aircraft Factory:	7456–7.
Darracq:	6378–6477, A4869–4987, A5491.
Vickers:	7595–7644, A41–65 (cancelled).
Rebuild:	A8894.

R.E.5

Royal Aircraft Factory:	26, 334–5, 361, 380, 382, 613, 617, 631, 651, 659, 660, 674, 677–8, 688, 737, 745, 2456–61.

R.E.7

Austin:	2237–2266, 6016–6115 (cancelled).
Coventry Ordnance Works:	2185–2334.
G & J Weir:	6828–6927 (cancelled).
Napier:	2287–2336, 7455–7594 (cancelled).
Siddeley Deasy:	2348–2447.
Unknown:	2235–6.

R.E.8

Royal Aircraft Factory:	7996–7, A66–115, A3506–3530.
Austin:	A3169–3268, A4261–4410, B5851–5900.
Coventry Ordnance Works:	A4664–4763, B6631–6730, B7681–7730, C5026–5125, D6701–6850.
Daimler:	A3531–3680, A4161–4260, B3401–3450, B5001–5150, C2231–3080, F3548–3747.
Napier:	A3832–3931, B2251–2300, C4551–4600, D3836–3910 (cancelled), D4811–4960, E1101–1150.
Siddeley Deasy:	A3405–3504, A3681–3830, B6451–6624, E1–300, E1151–1250, F1553–1602, F3246–3345.
Standard Motor:	A4411–4560, A4564–4663, D1501–1600, D4661–4810, F1665–1764.
Rebuilds:	A7000, B730, B732, B734, B737–8, B741–2, B750, B753, B755–760, B764–5, B780–3, B786–7, B791–3, B798, B810–11, B814, B820–825, B830, B832–3, B835–7, B840–6, B853, B876, B1498, B4021, B4028–30, B4032–36, B4038, B4040, B4045–6, B4048, B4050–1, B4054–57, B4059–60, B4062, B4065, B4067, B4069, B4075, B4086, B4089–90, B4093–94, B4097, B4101, B4103–6, B4109, B4118, B4134, B7734, B7738–40, B7754, B7761, B7802–5, B7827, B7834, B7853, B7887, B7893, B7917, B8097, B8798, B8872, B8874, B8876–78, B8880–91, B8893–8900, B8909, B9473, B9997, C3381, C3433, C4282, C4294, D4966–7, D4970, D4972, D4980–1, D4996, D4998, D9737–9, D9790–9799, F662–3, F666, F669, F672, F675–77, F681–85, F687, F689–90, F694, F699, F700, F5871–2, F5874–5, F5879–82, F5885, F5891, F5895, F5897, F5899, F5901–2, F5909, F5976, F6005, F6007, F6010, F6012–19, F6044–50, F6085, F6091, F6097, F6203–4, F6218, F6270, F6273, F6277, F6279, F6299, H6843, H6845, H6849, H6857, H6865, H6870, H6879, H6896, H6900, H7017–7038, H7040–57, H7136–7143, H7182–7193, H7207, H7262–7268, H8121.

S.E.5

Royal Aircraft Factory:	A4561–4563, A4845–4868, A8898–8947.

S.E.5a

Royal Aircraft Factory:	A4503, A4846, A8901, B4841,–4900, C1051–1150, D7001–7050.
Air Navigation:	B1–200, C1751–1950, E5937–6036, H674–733.

Austin:	B8231–8580, C8661–9310, E5637–5936, F7951–8200, H5291–5540 (cancelled).
Martin and Handasyde:	D3911–4010, E3154–3253, F5249–5348, F8321–8420.
Vickers:	B501–700, C5301–5450, C9486–9635, D201–450, D3426–3575, D5951–6200, D8431–8580, E1251–1400, E3904–4103, F551–615, F5449–5698, F7751–7800, F8946–9145.
Whitehead Aviation:	B1001–1100 (cancelled).
Wolseley Motors:	C6351–6500, D6851–7000, F851–950.
Rebuilds:	B733, B848, B875, B891, B6496, B7733, B7735, B7737, B7765, B7770–1, B7786, B7796, B7824, B7830–3, B7850, B7870, B7881, B7890–1, B7913, B8791, B8932, F4176, F4575, F5912, F5924, F5956, F6276, F6427, F6431–2, F9568, H7072–4, H7161–66, H7181, H7247–7254, H7256–7261.

S.E.5b

Royal Aircraft Factory:	8947.

Appendix 3

Royal Aircraft Factory engines (including postwar developments)

Type No	*Date*	*Description*	*H.P.*	*Bore*	*Stroke*	*Remarks*
R.A.F.1	1913	Air-cooled 90° V-8	90	100mm	140mm	Experimental prototype
R.A.F.1a	1914	Air-cooled 90° V-8	90	100mm	140mm	Production version of above
R.A.F.1b	1916	Air-cooled 90° V-8	105	105mm	140mm	Not adopted for production
R.A.F.1d	1917	Air-cooled 90° V-8	105	105mm	140mm	Experimental high-compression version of above
R.A.F.2	1913	Nine-cylinder air-cooled radial	120	100mm	140mm	Experimental engine only
R.A.F.3	1914	Water-cooled 60° V-12	200	4.3in	5.5in	Three prototypes built
R.A.F.3a	1915	Water-cooled 60° V-12	200	4.5in	5.5in	Production version of above
R.A.F.3T	—	Water-cooled 60° vee twin	—	4.5in	5.5in	Two experimental engines built to test R.A.F.3a components

R.A.F.4	1914	Air-cooled 90° V-12	140	100mm	140mm	Based on R.A.F.1
R.A.F.4a	1915	Air-cooled 90° V-12	140	100mm	140mm	Production version of above
R.A.F.4b	—	Air-cooled 90° V-12	170	105mm	140mm	Based on R.A.F.1b
R.A.F.4c	—	Air-cooled 90° V-12	170	100mm	140mm	As R.A.F.4, but with aluminium cylinders
R.A.F.4d	—	Air-cooled 90° V-12	200	100mm	140mm	Supercharged version of R.A.F.4
R.A.F.4e	1917	Air-cooled 90° V-12	200	100mm	140mm	Supercharged version of R.A.F.4
R.A.F.4T	1916	Crankcase only	200	100mm	140mm	Used to test experimental cylinder designs
R.A.F.5	1915	Air-cooled 60° V-12	140	100mm	140mm	Pusher version of R.A.F.4 with fan cooling
R.A.F.5a	1915	Air-cooled 60° V-12	140	100mm	140mm	Production version of above
R.A.F.5b	1915	Air-cooled 60° V-12	170	105mm	140mm	Pusher version of R.A.F.4b
R.A.F.5c	1915	Air-cooled 60° V-12	170	100mm	140mm	As R.A.F.5, but with aluminium cylinders — not built
R.A.F.5d	1915	Air-cooled 60° V-12	170	100mm	140mm	As R.A.F.5, but OHV — not built
R.A.F.6	1915	Air-cooled 90° V-8	90	100mm	140mm	Pusher version of R.A.F.1a
R.A.F.7	1917	Water-cooled 60° V-12	—	4.5in	5.5in	High-compression variant of R.A.F.3
R.A.F.8	1916	Air-cooled fourteen-cylinder two-row radial	—	4.75in	5.5in	Basis of Armstrong Siddeley Jaguar
R.A.F8T	1916	Parts to test R.A.F.8 cylinders on R.A.F.4T	—	—	—	—
R.A.F.9T	1916	Single-cylinder sleeve-valves	—	6.0in	8.0in	Experiments with sleeve-valve operation only
R.A.F.10	—	Twelve-cylinder water-cooled 'W' type	—	120mm	130mm	Inspiration for Napier Lion
R.A.F.11	—	Three-cylinder air-cooled	—	4.75in	5.5in	Project only — using R.A.F.8 cylinders
R.A.F.12T	1917	Opposed-piston double-acting two-stroke	—	—	—	Experimental only

R.A.F.13T	1917	Single-cylinder air-cooled	—	5.0in	6.0in	Four-valve cylinder tested on R.A.F.UT
R.A.F.14	—	Sixteen-cylinder air-cooled 'X' type	—	4.5in	4.5in	
R.A.F.15	1917	Air-cooled 60° V-12	—	4.25in	5.5in	
R.A.F.16	1918	Air-cooled 60° V-12	—	4⅞in	5¼in	
R.A.F.17T	1918	Air-cooled test cylinder	—	6in	—	Tested on R.A.F.UT
R.A.F.18T	1918	Air-cooled test cylinder with sleeve valve	—	4.5in	5.5in	Tested on R.A.F.UT
R.A.F.19	1918	Air-cooled test cylinder	—	6in	8in	
R.A.F.20	1918	Water-cooled test cylinder	—	8in	11in	
R.A.F.21T	1918	Air-cooled test cylinder	—	5.5in	6.5in	
R.A.F.21TD	1918	Air-cooled test cylinder	—	5.5in	6.5in	Designed for ABC Dragonfly
R.A.F.22TW	—	Air-cooled cylinder	—	4.5in	6in	Designed for ABC Wasp
R.A.F.22W	—	Air-cooled seven-cylinder radial	—	4.5in	6in	Redesign of ABC Wasp
R.A.F.23T	—	Air-cooled cylinder (two-valve)	—	5.75in	7.5in	Designed for Bristol Jupiter
R.A.F.24T	—	Air-cooled cylinder (four-valve)	—	5.75in	7.5in	Designed for Bristol Jupiter
R.A.F.25T	—	Air-cooled cylinder (four valves)	—	6in	—	Designed for Leopard
R.A.F.26T	—	Water-cooled two-stroke cylinder	—	5in	—	Tested on R.A.F.UT
R.A.F.27T	—	Air-cooled two-stroke cylinder	—	5in	—	Tested on R.A.F.UT
R.A.F.UT	1917	Crankcase only	—	—	—	Designed for cylinder testing

Appendix 4

Survivors and reproductions

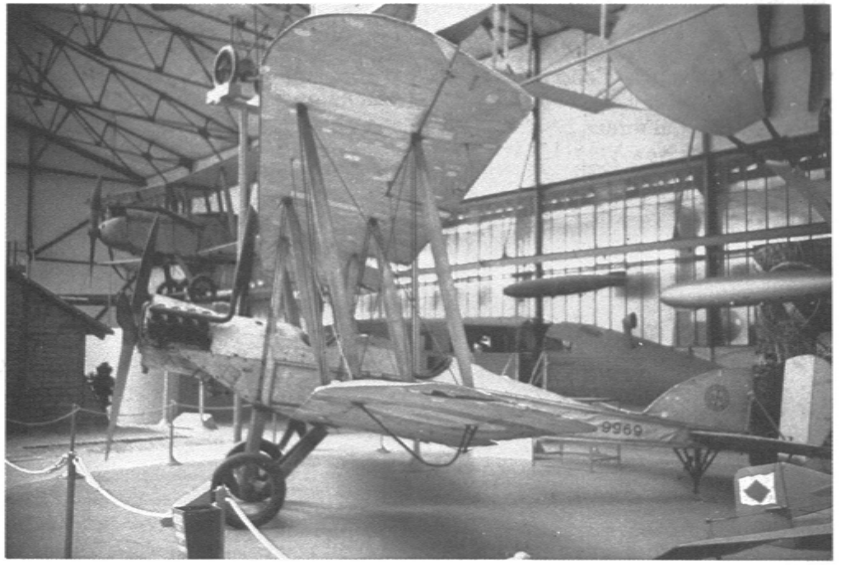
A small number of Royal Aircraft Factory-designed aeroplanes have survived to this day. All of them are now preserved in museums.

Several R.A.F. engines are also extant in addition to those fitted to the above aeroplanes and, while no complete airship survives, two control cars, one original and the other a replica, are displayed in museums.

The following is a list of all such items and their locations, and is correct at the time of writing (late 1989).

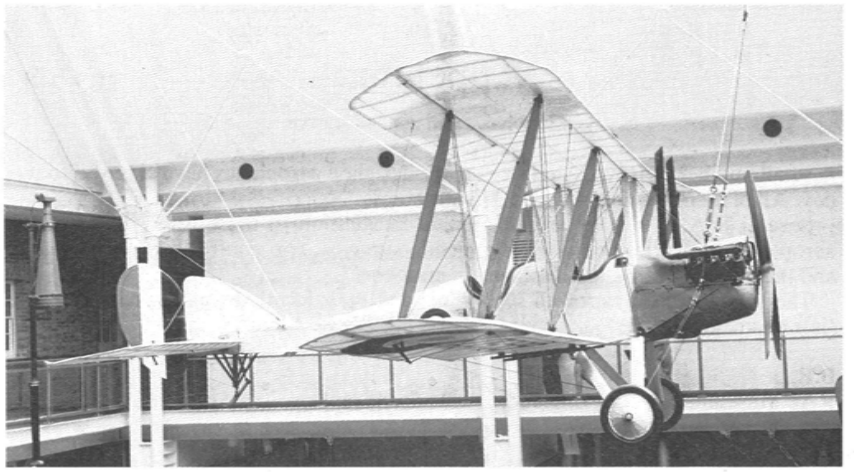
B.E.2a
RAF Museum, Hendon, England: Static replica — cockpit section only

B.E.2b
RAF Museum, Hendon, England: Static replica '687'



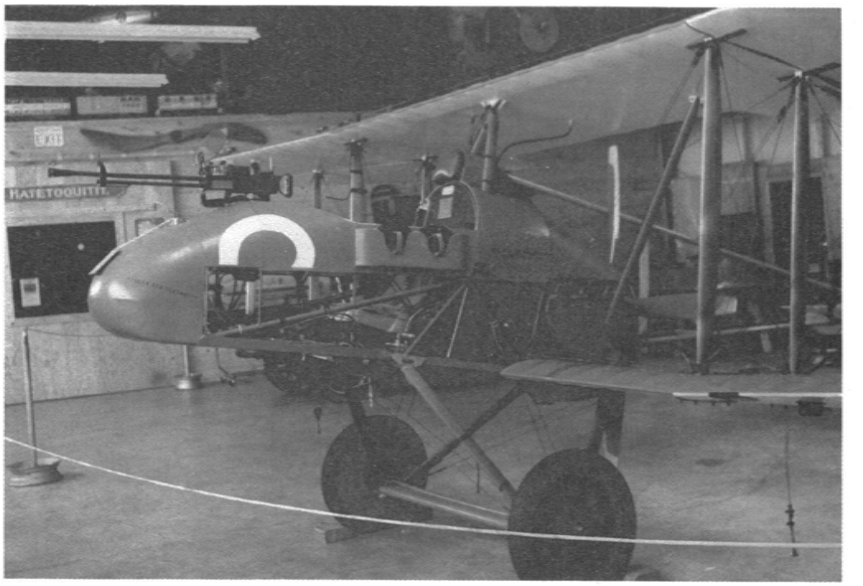
Blackburn-built B.E.2c 9969 on display at the Musée de L'Air, Paris, France, in 1980. The sump cowling and wheel covers are missing, and the fin is of the later B.E.2e pattern, a modification frequently carried out in service.

B.E.2c
Imperial War Museum, London, England: Static original — serial 2699
Musée de l'Air, Paris, France: Static original — serial 9969



The beautifully restored B.E.2c 2699 on display at the Imperial War Museum, London.

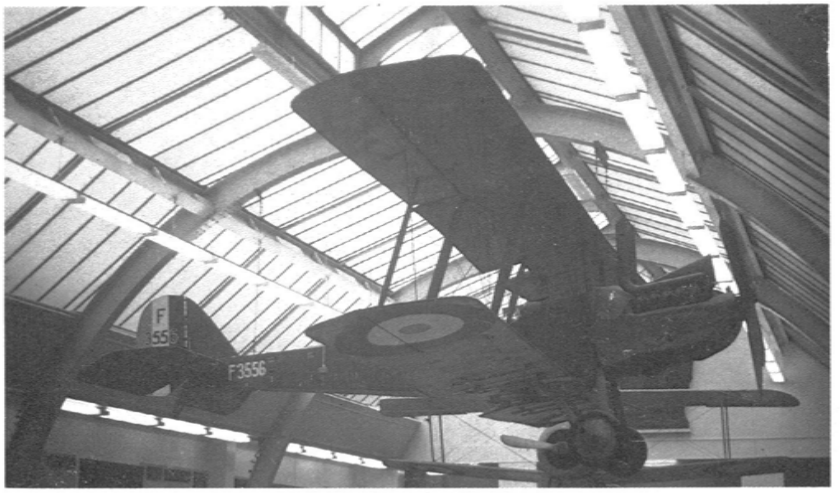
National Aeronautical Collection, Ottowa, Canada:	Static original — serial 4112, awaiting restoration
Private owner, California, USA:	Flying reproduction — under construction
Old Rhinebeck, New York, USA:	Flying reconstruction — converted from Tiger Moth for film work — awaiting restoration
Brooklands Museum, Surrey, England:	Reproduction — BAPC 117
B.E.2e	
National Air Force Collection, Norway:	Static original — serial 131, ex 1380
Mosquito Museum, Hertfordshire, England:	Static original — under restoration
F.E.2b	
RAF Museum, Hendon, England:	Static replica (under construction)
F.E.8	
Old Rhinebeck, New York, USA:	Flying reproduction
Owl's Head Museum of Transport, Maine, USA:	Flying reproduction
R.E.8	
Imperial War Museum, Duxford, England:	Static original — serial F3556
Musée Royal de l'Armée, Brussels, Belgium:	Static original — serial A4719, 200hp Hispano-Suiza
S.E.5a	
Shuttleworth Collection, Bedfordshire, England	Flying original — serial F904



A replica F.E.8 on display at the Owl's Head Museum of Transportation, Maine, USA.
(GL Burr)

The replica F.E.8 built and flown by Cole Palen at Old Rhinebeck Aerodrome, New York, USA.
(via C Palen)

RAF Museum, Hendon, England:	Static original — serial F938, ex-'B4563'
Science Museum, London, England:	Static original — G-EBIB ex-F939, in skywriting configuration
England (location unknown)	Flying original (Eberhart-built), restored to flying condition as an S.E.5a ('B4863') for the late The Hon Patrick Lindsay.

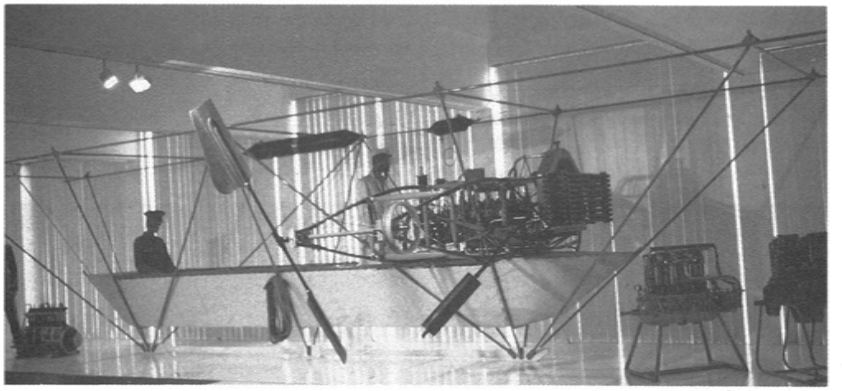


R.E.8 F3556 at the Imperial War Museum in London before its transfer to Duxford for restoration and display.

This original S.E.5a is now part of the Shuttleworth Collection at Old Warden Aerodrome, Bedfordshire, England, where it performs regularly in flying displays.

National Museum, Bloemfontein, South Africa:	Static original — serial 320, ex-F7781
Australian War Memorial, Canberra, Australia:	Static original – serial C9539
USAF Museum, Dayton, Ohio, USA	Static original (Eberhart-built)

In addition, a number of reproductions, of varying degrees of accuracy, are either flying or under construction. Their number, status and ownership are too fluid to be recorded in a book of this kind.



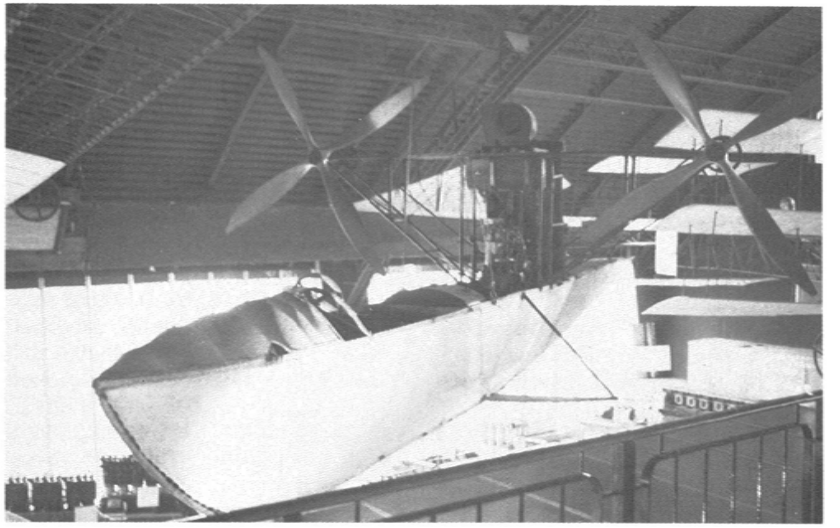
A replica of the car of *Nulli Secundus* on display at the Royal Air Force Museum, Hendon, London. Note the crossed drive belt to the starboard propeller. The dummy in the white dustcoat is a little too slender to represent S F Cody.

Airship *Nulli Secundus*

RAF Museum, Hendon, England:	Replica of car

Airship *Beta II*

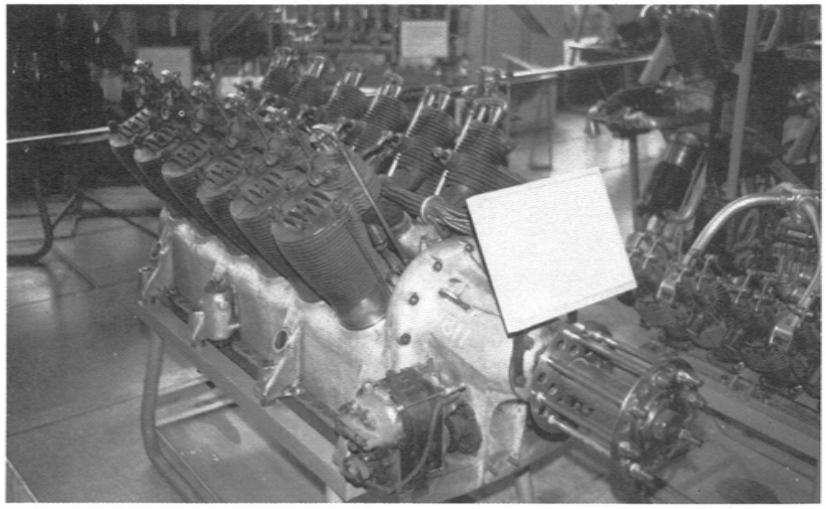
Science Museum, London, England:	Original car



The car of the airship *Beta*, complete with its 35hp Green engine, preserved in the Science Museum, South Kensington, London. The blower fan above the engine was used to inflate the ballonet.

R.A.F.1a engine
Science Museum, London, England: Original

R.A.F.4a engine
Science Museum, London, England: Original
Musée Royal de l'Armée, Brussels, Belgium: Original



An R.A.F.4a engine preserved in the Science Museum, South Kensington, London.

General Index

Advisory Committee for Aeronautics 25, 37, 57, 69, 83
The Aero 29
The Aeroplane 42, 47, 49, 52, 67, 70, 72, 73, 86, 170
Air Battalion 31, 32, 36, 37, 41, 45, 119, 134, 164
Aircraft Manufacturing Company 68, 82, 107
airship shed 10, 14, 17, 20, 25, 26, 27, 29, 32, 58, 59, 62, 83, 221
Alexander, Patrick Y 44, 205
Allen, Capt C R W 72
Andover Advertiser 44
Archdeacon, Ernest 15
Arthur, Lt D 170
Army Aircraft Factory 36, 37, 42
Asquith, H H 22

Baden-Powell, Capt B F S 5
Bailhache, Justice 95, 103, 104, 105
Ball, Albert 284, 285
Balloon Equipment Store 2, 5
Balloon Factory 5, 7–11, 16, 20, 21, 22, 25, 26, 28, 30, 34, 42
Balloon Square 8
Bannerman, Sir Alexander 29, 30, 52
Beaumont, Capt F 1
Becke, Capt J H W 251
Billing, N Pemberton 91, 93, 94, 107, 152
Black Sheds 32, 45, 67, 72
Blackburn Aircraft Company 82
Blair Atholl 12, 16, 17
Bleriot, Louis 21
Blomfield, Maj 205
Blood, Capt B 281
Bloody April 107
Boer War 6
Boulton & Paul Limited 207, 215
Brancker, Maj W S 77, 148
British and Colonial Aeroplane Company 55, 139, 159, 173, 180
Brooke-Popham, Gen 260
Burbidge, Sir Richard 93, 113
Burke, Capt 45
Busk, Edward T 51, 53, 57, 61, 75, 76, 80, 141, 146, 147, 148, 240, 242, 248

Cammell, Lt 31, 269
Capper, Col J E 7, 8, 9, 10, 11, 12, 13, 15, 16, 19, 23, 24, 25, 26, 27, 29, 88, 115
Carden, Capt 11, 14
Central Flying School 50, 86, 135, 168, 169, 171, 173, 178, 223
Chalais Meudon 7, 30
Chanute, O 10
Cody, S F 8, 9, 11–21, 29, 54, 56, 80, 115, 269, 311
Cody, V 10
Cody's Tree 67
Constantinesco gear 261, 284, 298
Coventry Ordnance Works 173, 175, 183, 186
Coventry Ordnance Works Gun 219, 221, 225, 226, 237
Cowdray, Lord 262
Coxwell, Henry 1
Crystal Palace 15, 116
Curzon, Lord 96

Daily Mail 93
Daimler Company 26, 39, 105, 183, 186
Darracq Motor Company 228
Davis gun 183
De Havilland, Geoffrey 31, 36, 37, 39, 40, 41, 43, 44, 46, 49, 53, 54, 59, 68, 87, 131, 132, 133, 134, 137, 138, 164, 167, 171, 191, 196, 197, 199, 200, 202, 221, 240, 269, 270, 272, 273
Dickson, Bertram 28
Douglas, W Sholto (Lord Douglas of Kirtleside) 84, 179, 291

Dunne, J W 11–18, 20, 21, 28, 269

Edward VII, King 13, 15
Esher, Lord 20, 21
Ellor, J E 107

Farnborough Common 19, 22, 30, 36, 40, 42, 56, 60, 62, 71, 73, 115, 117, 133, 168
Farren, W S 88
fiery grapnel 89
Fleet Pond 200
Flight 41, 53, 58, 60, 64, 66, 70, 74, 75, 103
Folland, Henry P 39, 78, 81, 82, 103, 113, 129, 221, 240, 276, 280, 281, 283, 284
Follett, Capt 37
Fowler, Henry 103, 113, 114

George V, King 49, 61, 75, 138, 168, 222
Gerrard, Maj 171
Gibbs, Lt L 16, 17, 28
Gibson, A H 100
Glazebrook, Dr 22, 25, 51, 95
Glover, Lt G 1
goldbeater's skin 2, 7, 8, 64, 115, 117
Goodden, Frank 77, 87, 101, 105, 178, 187, 206, 222, 223, 228, 229, 260, 273, 281, 285
O'Gorman, M J P 24–27, 29–33, 35–39, 42, 43, 47, 48, 51, 53, 54, 57, 58, 59, 61, 62, 66, 74, 88, 95, 97, 103, 107, 114, 138, 160, 164, 191, 247, 248, 269, 273, 276
Graham-White, C 34
Green, F M 26, 31, 40, 49, 74, 77, 88, 107, 138, 269, 298
Grey, Charles C 29, 42, 43, 47, 49, 50, 52, 56, 67, 70, 72, 82, 84, 85, 86, 93, 95, 105, 139

Hadden, Sir Charles 21, 25
Haldane, Lord 21, 28
Hall, L 107
Handley-Page Limited 56
Haynes, E T 202
Hearle, F 31, 49
Heckstall-Smith, S 40, 46, 88
Henderson, Gen 53, 95, 104
Heron, S D 100, 107
Hewlett, Mrs R B 70
Hewlett & Blondeau Limited 70, 76
Hill, Roderic 109, 232, 288
Hiscocks, S W 26, 39, 82, 88, 138
Hucks, B C 228

Iris Motor Company 31, 41, 196
Irving, J S 44, 107
Issy-les-Moulineaux 15

Jersey Brow 48, 72, 83, 114
Jones, Lt H B 5
Jones, Lt Trafford 209, 216
Joubert de la Ferte, Lt 144
Joynson-Hicks, Mr 43, 72, 95

Kemp, Ronald 68, 71, 202, 221
Keith-Lucas, Dr S 110
Kenworthy, J 87, 171
King, Capt W 14
Kitchener, Lord 84

Laffan's Plain 18, 20, 21, 32, 50, 55, 61, 100, 199, 246
Lanchester, F 22, 26, 100
Langley, Prof S P 10
Larkhill 31, 52, 199
Lee, Capt H P 1, 2
Leefe-Robinson, W 155, 156
Lefroy, Capt H 31
Lewis gun 127, 151, 183, 189, 204, 207, 208, 211, 214, 226, 228, 238, 260, 261, 281, 284, 289, 298
Liddell, Capt W A 253
Lindemann, F A 108
Lloyd, J 107
Lloyd George, David 22
Longcroft, Capt 143
Loraine, R 28
Low, Capt A M 103, 129

McDonald, Col J 7
McWade, Mr 37
Maitland, Capt E M 119, 124
man-lifting kites 5, 9
Mapplebeck, Lt G W 144
maxim gun 200

Mayo, R P 80
Medlicott, Lt 151
mooring mast 37, 119, 122
Morning Post 29, 30, 36
Moseley, H 41, 44

Napier Limited 75, 78
National Physical Laboratory 11, 12, 22, 25, 38, 51, 57, 95, 98, 99, 117, 195
Nieuport and General Aircraft Company 107, 113

Oerlikon Company 28

Paine, Capt 53
Palmer Cord Aero Tyre Company 66
Parke, Lt 100
Perry, C 134, 200
Pinehurst Cottages 83, 113
Preston, H 107, 129
Pyestock chimney 100, 109

Ramsbottom, Dr J E 84, 124
Rayleigh, Lord 25
reports and memoranda 38, 42, 50, 73, 74, 103, 112, 140
Rhodes-Moorhouse, Lt W B 146
Ridge, Lt T 27, 39, 40, 197, 271
ripograph 61, 71
Roberts, Lord 30
Roe, A V 56, 57
Rolls, The Hon C S 20, 29
Rolls-Royce Limited 20, 25, 78
Royal Air Force 5, 127, 293
Royal Australian Air Force 186
Royal Flying Corps (RFC) 5, 48, 50, 55, 68, 84, 88, 91, 105, 112, 141, 144, 161, 165, 171, 173, 209, 230, 279
Royal Flying Corps (RFC)
No. 1 Squadron 173
No. 2 Squadron 134, 169, 170
No. 3 Squadron 165, 169, 173
No. 4 Squadron 144, 171
No. 5 Squadron 173
No. 6 Squadron 171, 173, 179, 251
No. 7 Squadron 173, 253
No. 8 Squadron 179
No. 13 Squadron 79, 232
No. 16 Squadron 179
No. 22 Squadron 215
No. 34 Squadron 261
No. 37 Squadron 184
No. 56 Squadron 285
No. 78 Squadron 223, 238
No. 100 Squadron 215
Royal Navy 18, 20, 126, 148, 250
Royal Naval Air Service (RNAS) 64, 68, 112, 141, 155, 157
Royal Society 61, 100
Rushton, Proctor Limited 159

Salisbury Plain 28, 31, 52, 53, 77, 144, 148, 199, 269
Salmond, Capt J 144, 279
Santos-Dumont, A 7, 11
Scarff ring 261, 298
School of Ballooning 2, 5, 23, 28, 29, 31
Searle, F C 188
Seely, Col 43
Short Brothers 20
Short, F 53
Siddeley Deasy Car Company 107, 262, 298
Sidney-Smith, W 114
Smith-Barry, Lt R 173
Smithsonian Institution 10
Southern Aeroplane Repair Depot 83, 113, 188, 215
Spratt, Norman 77, 251, 278
St Louis World's Fair 9
St Paul's Cathedral 15, 116
Supermarine Aircraft Company 91
Swan Inn 8, 19, 63
Sykes, Maj FH 53, 54, 138

Taylor, G 100
Templer, Col J L B 1–8, 10, 13, 23, 88, 115
The Times 19, 68, 75, 76
Thurston, Dr A P 285
trajectograph 52, 53
Trenchard, Gen H 208, 225

Vickers Limited 56, 107, 139, 149, 172, 175

Vickers machine gun 184, 288, 294, 298
Vickers rocket gun 236, 237
Vulcan Limited 159

Warneford, Lt R 156
Waters, S J 78, 82, 219, 221
Watkins, Lt L P 184
Westlake, Lt 16
Weinling family 2
Weir, Sir William 113
Westminster, Duke of 131
Wilson, Gen H H 7
wind tunnel 11, 12, 21, 25, 60, 63, 86, 98, 109, 112
wireless 28, 46, 96, 103, 119, 122, 124, 138, 143
Woleseley Motors Limited 147, 161, 288
Woodlands Cottage 32
Woolwich Arsenal 1
Wright Brothers 10, 11, 15

Index of Engines

A B C Gnat 129, 299
Antoinetter 12, 14, 16, 18, 115
Armstrong-Siddeley Jaguar 107
Austro-Daimler 206, 225, 248, 249, 250, 251, 254, 299

Beardmore 207, 210, 212, 216, 251, 254, 257, 258, 299
Bentley B.R.1.: 129
Bentley B.R.2.: 127
Buchet 12hp 12, 13, 21, 22, 118

Canton-Unne 125, 126
Chenu 219, 221, 299
Clerget 119, 120, 175, 176, 228, 281
Curtiss O × 5: 155

ENV F 36, 169, 170, 270, 272, 299

Gnome rotary 39, 49, 50, 59, 77, 87, 165, 167, 168, 171, 172, 173, 175, 176, 190, 199, 200, 202, 227, 231, 272, 274, 276, 278, 281, 299
Green 27, 45, 78, 118, 120, 123, 205, 206

Hispano-Suiza V8: 88, 111, 127, 154, 162, 188, 190, 231, 233, 234, 235, 236, 237, 239, 267, 283, 284, 287, 288, 294, 297, 298, 299

Iris 45hp 31, 41, 122, 123, 196, 198

R E P 22, 118, 119, 120
Renault V8: 45, 53, 62, 64, 134, 135, 136, 138, 145, 157, 169, 170, 180, 201, 203, 204, 241, 243, 245, 299
Renault V12: 245, 246, 299
Le Rhône 228, 281
Rolls-Royce
  Eagle 215, 216, 218, 223, 226, 256, 257, 258, 265
  Falcon 256
  Hawk 155

Royal Aircraft Factory
  R.A.F. 1: 64, 65, 73, 80, 88, 105, 149, 155, 157, 162, 180
  R.A.F. 2: 66
  R.A.F. 3: 77, 78, 107, 194, 195, 222, 256, 299
  R.A.F. 4: 80, 95, 180, 182, 222, 224, 254, 258, 265, 266, 269, 297, 299
  R.A.F. 5: 210, 222, 223, 224
  R.A.F. 8: 107, 297

Siddeley Puma 218
Sunbeam
  Arab 127, 291, 299
  Maori 194, 195, 255

White and Poppe 41, 124, 125
Wolseley
  60hp V8: 43, 45, 131, 134, 135, 299
  Adder 294
  Viper 289, 291, 294, 296

Index of Aircraft

Aircraft Manufacturing Company
  D.H.2: 87, 227, 228, 231
Albatros 152
Armstrong Whitworth F.K.8: 96
Astra-Torres 47
Avro biplane 100, 246

Blackburn TB 82
Bleriot XI 21, 33
Bleriot XII 31, 36, 40, 269
Bleriot XXI 31
Breguet 45
Bristol biplane 28, 43
Bristol F.2b Fighter 96, 298
British Army Aeroplane No. 1: 18, 19, 20, 55, 138

Clement-Bayard 31
Cody Cathedral 55, 138
Cody glider kite 10
Cody power kite 12, 13, 21

De Havilland biplane 31, 35, 196
Dunne D1 13
Dunne D3 16, 17
Dunne D4 16, 17

Farman biplane 28, 29, 34, 46
Farman, Maurice 54
Felixstowe F.2 195
Fokker monoplane 84, 85, 86, 91, 92, 108, 152

Hanriot 54
Handley-Page O/400 114
Handley-Page V/1500 112

Lebaudy (*Morning Post*) 29, 30, 36

Martin and Handasyde 54

Poulhan 29, 43, 164

Royal Aircraft Factory
Aerial Target 103, 129, 299
  Baby 21, 22, 27, 117
  Beta 28, 40, 117, 311
  Gamma 27, 40, 41, 61, 120, 125
  Delta 31, 32, 41, 57, 61, 123, 124
  Eta 64, 124, 125
  Epsilon 68, 126
  Nulli-Secondus 13–17, 28, 115, 311
  Nulli-Secondus II 16, 115
  A.E.1 127, 219
  A.E.2 127
  A.E.3 112, 127, 299
  B.E.1 43, 44, 45, 46, 59, 131, 136, 137, 164, 169, 299
  B.E.2 11, 45, 46, 49, 50, 51, 53, 54, 55, 57, 60, 62, 66, 67, 69, 73, 74, 76, 77, 78, 79, 82, 85, 86, 87, 88, 91, 92, 93, 94, 95, 98, 100, 104, 105, 106, 107, 108, 110, 136, 164, 169, 170, 172, 175, 176, 177, 178, 180, 181, 182, 183, 184, 186, 200, 201, 205, 206, 207, 241, 258, 261, 267, 299, 300, 307, 308
  B.E.3 48, 49, 53, 57, 59, 164, 167, 168, 170, 171, 190, 191, 245, 299
  B.E.4 53, 57, 72, 73, 166, 167, 169, 170, 171
  B.E.5 169
  B.E.6 61, 142, 170
  B.E.7 171, 299
  B.E.8 69, 171, 299, 300
  B.E.9 86, 177, 235, 299
  B.E.10 180
  B.E.11 181
  B.E.12 98, 182, 232, 300
  B.S.1 59, 190, 272, 273, 276, 299
  B.S.2 192
  C.E.1 111, 112, 193, 299
  F.E.1 35, 36, 38, 39, 196, 199
  F.E.2 39, 46, 61, 62, 68, 71, 72, 78, 87, 98, 104, 111, 198, 199, 221, 223, 225, 231, 237, 254, 256, 299, 300, 308
  F.E.3 63, 219, 225, 227, 299
  F.E.4 78, 221, 224, 225, 226, 299

F.E.5 224
F.E.6 225, 227, 299
F.E.7 226
F.E.8 87, 98, 101, 102, 227, 232, 299, 300, 308, 309
F.E.9 111, 187, 231, 237, 299
F.E.10 88, 235, 284
F.E.11 236
F.E.12 236, 237
H.R.E.2 63, 166, 237, 245, 246
H.R.E.6 237
N.E.1 112, 127, 234, 237, 299
R.E.1 61, 75, 76, 193, 240, 244, 245, 299
R.E.2 63, 237, 244, 248, 249, 299
R.E.3 247, 248, 249, 299
R.E.4 249
R.E.5 68, 225, 247, 248, 249, 253, 254, 299, 300
R.E.6 237, 253
R.E.7 80, 98, 252, 253, 300
R.E.8 95, 96, 98, 109, 232, 258, 267, 268, 299, 301, 309, 310
R.E.9 267
S.E.1 37, 38, 39, 40, 42, 53, 136, 170, 269, 299
S.E.2 191, 272, 276, 277, 299
S.E.3 276
S.E.4 77, 82, 98, *276,* 299
S.E.5 88, 105, 107, 108, 110, 113, 188, 232, 236, 267, *283,* 298, 299, 301, 302, 308, 310
S.E.6 297
S.E.7 297
T.E.1 298

SPAD A-2 180
SS Class 155
Santos Dumont 14bis 33
Santos Dumont No 6: 7
Schutte-Lanz SL11 155
Siddeley R.T.1 107, 268
Sopwith Camel 291
Sopwith Pup 108
Sopwith Tabloid 59

Tarrant Tabor 114

Vickers Vimy 114
Voisin 34, 43, 131

Wright Flyer 11, 20, 29
Wright, Howard 50

Zeppelin 89, 91, 156, 184